

**BIOLOGY AND PARASITIC POTENTIAL OF ECTO-LARVAL PARASITOID,
Goniozus nephantidis (MUESEBECK) (BETHYLIDAE: HYMENOPTERA) UNDER
SOUTH GUJARAT CONDITIONS**

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BY**

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ABSTRACT



Biology and parasitic potential of ecto-larval parasitoid, *Goniozus nephantidis* (Muesebeck) (Bethyridae: Hymenoptera) under south Gujarat conditions

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ABSTRACT

Investigation on ‘Biology and parasitic potential of ecto-larval parasitoid, *Goniozus nephantidis* (Muesebeck) (Bethyridae: Hymenoptera) under south Gujarat conditions’ was undertaken at PG Research laboratory and Bio-control laboratory, Department of Entomology, N.M. College of Agriculture, Navsari Agricultural University, Navsari during 2015 to 2016.

Study on the biology of *G. nephantidis*, revealed that the maximum number of eggs were laid on the on dorso- lateral side on 5th to 6th abdominal segments of *C. cephalonica*. The freshly laid eggs were creamy white in colour and later become translucent. The average length of egg was 0.48 ± 0.06 mm, whereas the average breadth of egg was 0.23 ± 0.03 mm. The incubation period was 2.10 ± 0.71 days. The average egg hatching of *G. nephantidis* on *C. cephalonica* was 87.03 ± 5.86 per cent. The first instar larva of *G. nephantidis* was apodous, white, devoid of any sign of external segmentation. The later instar larvae were whitish yellow and having clear larval segmentation. The full grown larvae with tapering ends and bulge middle portion of larval body. The average larval length was 2.17 ± 0.11 mm and while the breadth was 0.43 ± 0.08 mm. The larval period of *G. nephantidis* was 4.03 ± 0.81 days. The cocoon of *G. nephantidis* was made loosely woven by silken threads and white in

colour with oblong in shape and become tough attached with substrate. The length of *G. nephantidis* cocoon was 3.98 ± 0.61 mm; while breadth was 1.98 ± 0.52 mm. The average pre-cocoon period was 1.53 ± 0.51 days. The cocoon period was 5.53 ± 1.00 days during the present investigation

The newly emerged adults of *G. nephantidis* were black in colour with transparent membranous wings; the antennae were filliform with 13 segmented. The average length and breadth of male was 1.25 ± 0.13 mm and 0.51 ± 0.13 mm, respectively while the average body length and breadth of female was 1.83 ± 0.42 mm and 0.94 ± 0.30 mm, respectively. The average pre-oviposition period, oviposition period and post oviposition period of *G. nephantidis* were 4.70 ± 0.95 , 18.63 ± 3.27 and 2.80 ± 0.76 days, respectively. The average sex ratio (Male: Female) of *G. nephantidis* was 1: 4.45. The adult emergence of *G. nephantidis* was 83.06 ± 5.38 per cent. The average male and female longevity of *G. nephantidis* on *C. cephalonica* was 13.77 ± 3.05 and 26.40 ± 3.39 days, respectively. The average fecundity of *G. nephantidis* was 72.57 ± 13.41 eggs per female. The total life cycle of male and female was 26.97 ± 3.45 and 39.33 ± 3.24 days, respectively.

The present investigation on parasitic potential of *G. nephantidis* on factitious host, *C. cephalonica* under laboratory conditions revealed that parasitoid paralyzed the larva of *C. cephalonica* within 2 to 3 hours after release. The female examines the host for about 20 to 25 seconds. The average number of larvae parasitized by adult parasitoid of *G. nephantidis* was 6.07 ± 1.55 . The average clutch size of *G. nephantidis* was 8.97 ± 2.09 eggs per larva.

The result of the study on relative toxicity of different insecticides against *G. nephantidis* revealed that there was no insecticide under testing found totally safe except control treatment (water spray) to the adults of *G. nephantidis*. However, spinosad 45 per cent SC was comparatively harmless to the adults. Moreover,

indoxacarb 15.8 per cent EC, emamectin benzoate 5 per cent SG, quinalphos 25 per cent EC, flubendiamide 39.35 per cent EC and profenofos 50 per cent EC were slightly harmful. Furthermore, triazophos 40 per cent EC, dichlorvos 76 per cent EC and chlorpyrifos 20 per cent EC were moderately harmful, while none of insecticide was categorized as harmful to the adults of *G. nephantidis* under laboratory condition.

The results on natural occurrence of larval parasitoids of black headed caterpillar under Navsari conditions indicated that the two larval parasitoids viz., *G. nephantidis* and *Habrobracon hebetor* Say were noticed on *Opisina arenosella* Walker. Among them, *G. nephantidis* was the dominant species under Navsari condition of Gujarat state. The maximum parasitism of *O. arenosella* by *G. nephantidis* and *H. hebetor* was observed during 2nd fortnight of May (17.69 and 15.65%) for the both parasitoids, respectively. However, the lowest per cent of parasitism by *G. nephantidis* was found during 1st fortnight of the October (2.23%). Moreover, the per cent parasitism of *H. hebetor* was nil during 1st fortnight of the August to 1st fortnight of the September. The highest numbers of *O. arenosella* larvae were parasitized by *G. nephantidis* and *H. hebetor* during 2nd fortnight of May (52 and 46 larvae), respectively. The total number of adults of *G. nephantidis* and *H. hebetor* emerged from host larvae were maximum during 2nd fortnight of May (347 and 213 adults), respectively. Moreover, the number of adults of *G. nephantidis* emerged from single larva was highest during 2nd fortnight of the September (8.80 adults/larva), while the maximum adults of *H. hebetor* emerged from single larva was noticed during 2nd fortnight of the February (7.57 adults/larva).

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C E R T I F I C A T E

This is to certify that the thesis entitled **“BIOLOGY AND PARASITIC POTENTIAL OF ECTO-LARVAL PARASITOID, *Goniozus nephantidis* (MUESEBECK) (BETHYLIDAE: HYMENOPTERA) UNDER SOUTH GUJARAT CONDITIONS”** submitted by **Mr. R. NAGANNA** in partial fulfillment of the requirements for the award of the degree of **MASTER OF SCIENCE** in the subject of **AGRICULTURAL ENTOMOLOGY** of Navsari Agricultural University is a record of bona fide research work carried out by him under my guidance and supervision and that the thesis has not been previously formed the basis for the award of any degree, diploma or has been published for other similar title. He has duly acknowledged all the assistance and help received during the course of the investigation.

Place: Navsari

Date: 23/06/2016

(C. U. Shinde)

Major Advisor

D E C L A R A T I O N

This is to declare that the whole of the research work reported herein the thesis for the partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **AGRICULTURAL ENTOMOLOGY** by the undersigned is the result of investigation carried by him under direct guidance and supervision of Dr. C. U. Shinde, Assistant Professor, Department of Agricultural Entomology, N. M. College of Agriculture, Navsari Agricultural University, Navsari and no part of the work has been submitted for any other degree so far.

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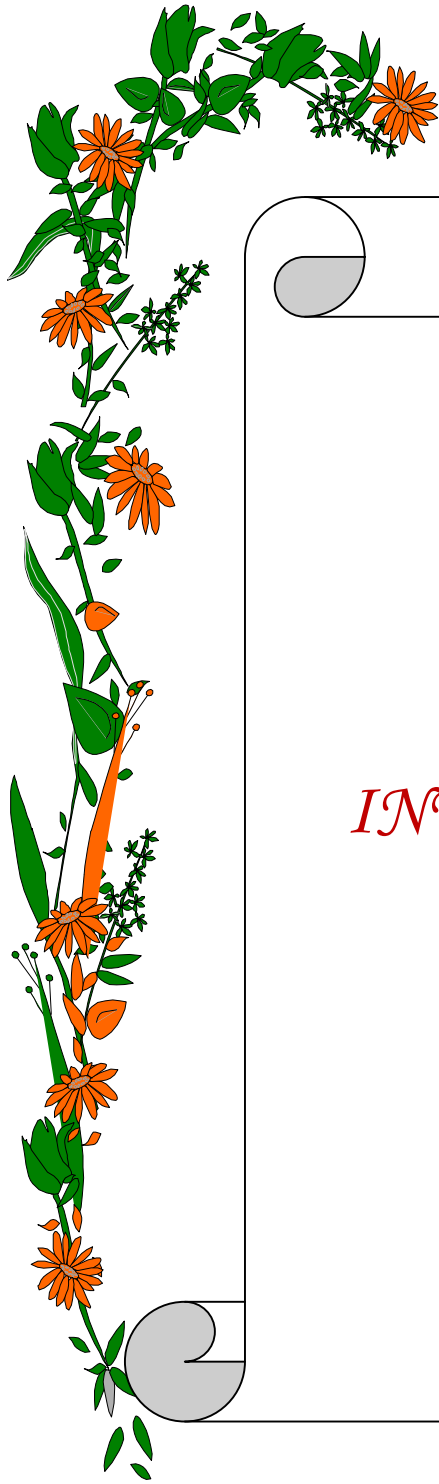
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INTRODUCTION



I. INTRODUCTION

The coconut palm, *Cocos nucifera* L. belongs to family Areaceae is “Tree of Life” as well as “*Kalpa vriksha*” provides livelihood to billions of people across the world. Coconut is widely cultivated in all the tropical regions of the world, growing particularly well in coastal areas near the sea on sandy beaches where it can tolerate salt spray and brackish soils. It is also grown under different soil types such as loamy, laterite, coastal sandy, alluvial, clay and reclaimed soils of the marshy low lands. The world coconut production has grown steadily over the period. India is third leading country after Philippines, Indonesia in harvested area of coconuts among the Asian countries. In India, area under coconut plantation during the year 2013-14 is 2140 Lakh hectares with production of 21665 million nuts and productivity of 10122 nuts per hectare whereas under Gujarat condition the area of coconut is about 31.63 thousand hectare with the production of 295.03 million nuts and productivity of 9328 nuts per hectare. In case of Gujarat, Junagadh district is leading producer followed by Valsad, Bhavnagar, Bhuj-Kutch and Amreli districts (Anonymous, 2016).

The major factors that contribute to the loss of production and productivity in coconut are damage due to environmental, fungal diseases and insect pests. The coconut palm is infested by a number of insect pests (Table-01). Among them, *Opisina arenosella* Walker causes the severe damages to the foliage, depriving the palm of its photosynthetic area and thus, directly affecting the yield (Sujatha and Chalam, 2009). The black headed caterpillar, *O. arenosella* is one of the serious and endemic pest of coconut in India (Cock and Perera, 1987; Rukhsana and Majeed, 2014; and Gurav *et al.*, 2014). The caterpillar is gregarious in habit and is voracious feeders. This pest living in galleries constructed with silk and frass on the under surface of the leaves, they feed by scraping out the green parenchyma of the

leaflet and leaving a thin parchment like upper epidermis. When dry, they form conspicuous grey patches on the upper surface of the fronds.

Table-01: Major insect pests infesting the coconut, <i>C. nucifera</i> palm				
Sr. No.	Common name	Scientific name	Family/ Order	Reference
1.	Rhinoceros beetle	<i>Oryctes rhinoceros</i> (L.)	Scarabaeidae: Coleoptera	Geoffrey, (2013); Gurav <i>et al.</i> (2014)
2.	Red palm weevil	<i>Rhynchophorus ferrugineus</i> (Oliver)	Rhynchophoridae: Coleoptera	Robin <i>et al.</i> (2013) Gurav <i>et al.</i> (2014)
3.	Black headed caterpillar	<i>Opisina arenosella</i> Walker	Cryptophasidae: Lepidoptera	Gurav <i>et al.</i> (2014) Rukhsana and Majeed, (2014).
4.	Slug caterpillar	<i>Macropsectra nararia</i> Moore	Limacodidae: Lepidoptera	Rajan <i>et al.</i> (2011)
6.	White grub	<i>Leucopholis coneophora</i>	Scarabaeidae: Coleoptera	Prathibha <i>et al.</i> (2013)
7.	Scale insect	<i>Aspidiotus destructor</i> (Signoret, 1869)	Hemiptera: Diaspididae	Jayma and Ronald, (2007)
8.	Coconut Eriophyid mite	<i>Aceria guerreronis</i> Keifer	Eriophyidae: Prostigmata	Desai <i>et al.</i> (2009) Gurav <i>et al.</i> (2014); Balaji and Hariprasad, (2015)

Generally, the lower whorls of fronds are severely attacked. However, in severe infestation, the plants are completely defoliated, leaving only the central shoot unaffected. From a distance the crowns of the severely infested palms appear burnt like symptoms. In the following year, nut production may be poor quality, due to a reduced production of flower spikes and increase in premature nut fall, constriction of the trunk and retardation of growth (Muthiah, 2007; and David and Ramamurthy, 2012). Outbreaks of the pest occur usually under favourable congenial conditions. Moreover, the

infestation of pest under South Gujarat conditions reaches serious proportion during the hot months of March to May; thereafter sharp decline of population of the pest due to the onset of monsoon. The abundance of the pest directly correlated with the relative humidity and inversely proportional to the temperature and sunshine hours (Kapadia and Mittal, 1993 and Pushpalatha and Veeresh, 1995).

Earlier attempts pertaining to control this pest were mostly mechanical and cultural practices. The pruning of infested palms and hunting the fronds were advocated. The removal of the leaves affected the health and vigour of the trees thereby resulting in tender nut falls. Chemical management of the pest is not practicable, as the application of the insecticides is quite difficult because of the huge height of the palm. Even if a power sprayer is used, the spray fluid does not reach to the larvae easily due to the galleries surrounded by them. Aerial spraying is also not effective and desirable as the pest is found only on the undersurface of the leaflets. The indiscriminate use of pesticides leads to the serious problems viz., air and water pollution, and health hazards viz., detrimental effects on beneficial insects i.e. destruction of ecological cycle and development of 3R problems (Dhawan *et al.* 1992 and Preetha *et al.*, 2009). In spite of the above facts, there is an urgent need to develop ecologically based sound integrated pest management strategy.

Biological control is a living weapon and an excellent strategy over chemical control, which is a modern and prestigious adoption at global level. The growth and development of the coconut pest are affected by several natural regulating factors viz., parasitoids, predators and pathogens during its egg, larval, pre-pupal and pupal stages. The black headed caterpillar is attacked by many entomophagous insects during its developmental stages. Among them, *G. nephandidis* is a gregarious larval parasitoid and responsible for the reduction in the population of the pest under field conditions (Cock and Perera, 1987; Venkatesan *et al.* 2009^a and Rao *et al.*, 2013). The release of larval

(*Bracon hebetor* Say, *G. nephantidis*) and pupal (*Brachymeria nosatoi* Habu) parasitoids had laid down the pest population from 16.73 to 8.73 per cent per palm with 30 per cent parasitization (Venkatesan *et al.*, 2004 and Sujatha and Chalam, 2009).

In Gujarat, coconut climbing is very expensive due to non availability of expert climbers and the farmers are very reluctant to adopt the pest management practices in the crown area due to this difficulty. The potent bio agent, *G. nephantidis* may be recommended as larval parasitoid for black headed caterpillar management.

Despite the great potency of this important larval parasitoid, very scanty information is available on its biology, parasitic potential on *Corcyra cephalonica* (Stainton), seasonal abundance and relative toxicity of various insecticides under south Gujarat conditions. The intention of this study was to investigate the biological attributes of such highly potent parasitoid, *G. nephantidis* and find out the safer insecticides thereby incorporation of this parasitoid in IPM of Coconut under coastal belt of south Gujarat condition could be feasible in near future.

To fill up the lacunae and imminent the knowledge on these aspects, the present study had undertaken with the following objectives.

Objectives:

1. To study the various biological aspects of *G. nephantidis*.
2. To study the parasitic potential of *G. nephantidis* on *C. cephalonica*.
3. To test the relative toxicity of various insecticides against *G. nephantidis*.
4. To study the naturally occurring larval parasitoid of black headed caterpillar under Navsari condition.



*REVIEW
OF
LITERATURE*



II. REVIEW OF LITERATURE

It is marked from the perusal of literature on various aspects of *Goniozus nephantidis* (Muesebeck) that entomologist took special interest to give emphasis on these dominant natural enemies of insect's pest because of their parasitic habits and suppressing pest population of agricultural importance in present era of IPM. In this chapter attempts have been made to review the available literature on various research aspects of *G. nephantidis* as well as other larval parasitoids relevant to the study and presented under the following aspects.

- 2.1 Biological parameters of *G. nephantidis*.
- 2.2 Parasitic potential of *G. nephantidis* on *C. cephalonica*.
- 2.3 Relative toxicity of various insecticides against *G. nephantidis*.
- 2.4 Natural occurrence larval parasitoids of black headed caterpillar under Navsari condition.

The review pertaining to the biology of *G. nephantidis* are presented herewith.

2.1 Biological parameters of *G. nephantidis*

2.1.1 Egg

2.1.1.1 Site, pattern of egg laying

Gordh (1976) reported that *G. gallicola* prefers to lay eggs on the host dorsum, especially on 6-9th body segments. Moreover, eggs were not observed on 2nd, 13th, and 14th segments. Later on, Remadevi *et al.* (1978) observed that the ovipositional behaviour of *G. nephantidis* under laboratory condition. They reported that the maximum numbers of eggs were laid at 29-33⁰C temperature. The female paralyzed the host larvae and deposited eggs by glued on lateral side of the abdominal segments normally during 12:00 and 19:00 hours with peak between 16:00 and 18:00 hours. The eggs were hatched within 1 to 3 days.

Conlong *et al.* (1988) studied the biology of *G. natalensis* and reported that the eggs were laid transversely across to the host larvae, close to the intersegmental folds and the majority of eggs were laid on the lateral aspect while some on the dorsal aspect and the fewest on the ventral aspect. Thereafter, Remadevi *et al.* (1995) investigated the host preference of *G. nephantidis* in relation to coconut block headed caterpillar, *O. arenosella* and rice moth, *C. cephalonica*. In both hosts, eggs were laid on all the segments except the first thoracic and the last four abdominal segments. Among the abdominal segments, the most preferred segments for egg deposition was 2nd and 3rd segment of *O. arenosella*, whereas it was 4th and 5th segment of *C. cephalonica*. Moreover, the deposition of eggs at intrasegmental region was 91.35 and 86.19 per cent in *O. arenosella*; while it was 8.65 and 13.80 per cent in the case of *C. cephalonica*, respectively. The left side was mostly preferred in each host. In most of the egg clutches on *O. arenosella* at the head end faced to the caudal end of the host; while on *C. cephalonica* it was at the head end faced up to the head end of the host.

Elahe *et al.* (2012) observed the oviposition behaviour of *G. swirskiana* showed that the eggs were laid on hosts' surface approximately 24 hrs after stinging process. The egg laying process completed within 25 to 45 minutes. The females laid maximum of 113 eggs on *Batrachedra amydraula* Meyrick. The maximum numbers of eggs were laid on the 5th segment (lateral) and there were not any eggs on thorax, the first segment of abdomen and the last segment of abdomen. The results indicated that 64.20 per cent of the female deposited eggs on dorsal side, 29.10 per cent on lateral side and 6.70 per cent on ventral side. The time taken from paralysis to laying an egg was 20 to 30 minutes; the time for depositing a single egg varied from 45 to 70 seconds and eggs were laid parallel to the longitudinal body axis of the larvae.

2.1.1.2 Colour, shape and size

Gordh (1976) reported that the eggs of *G. gallicola* measured about 0.8 mm in length and 0.2 mm in diameter. The deposition of eggs on host larvae completed within 1.5 to 4.0 minutes, while egg hatching occurred within 24 to 36 hours after egg deposition. Moreover, Conlong *et al.* (1988) studied the biology of *G. natalensis* on *Eldana saccharina* Walker and the eggs were measured about 0.6 mm in length and 0.2 mm in width. Stinne and Hardy (2000) carried out an investigation on egg maturation of *G. nephantidis* by dissection of adult females found a pronounced difference in size, shape and colour of mature and immature eggs. The immature eggs were short, not fully opaque, and surrounded by nurse cells. The mature eggs were opaque, milky white in colour, elongated, almost cylindrical and measured about 0.5 mm in length and 0.1 mm in width. The females of *G. nephantidis* were able to mature eggs without feeding as adult. The honey feeding did not greatly influence the egg loads of younger adult females while it was delayed in case of older females.

Seetharama *et al.* (2007) studied the biology of *Apenesia sahyadrics* (Azevedo and Waichert) and result revealed that the eggs were elongated, oval with the portion attached to the body of the host being slightly concave and translucent pale white in colour. The length of eggs varied from 0.64 to 0.85 mm (Av. 0.78 ± 0.01 mm) while width of eggs ranged from 0.29 to 0.36 mm (Av. 0.30 ± 0.004 mm).

Sreekanth and Muralimohan (2013b) reported that the size of the eggs produced by smaller and larger females of *G. nephantidis* were same and measured about 0.50 ± 0.01 mm in length and 0.15 ± 0.01 mm in width. Shah *et al.* (2014) observed that the morphometrical characters of *B. hebetor* and results found that the maximum and minimum length was 0.40 and 0.67 mm, respectively (Av. 0.57 mm). The minimum and maximum breadth of eggs was 0.13 and 0.18 mm, respectively (Av. 0.15 mm).

2.1.1.3 Incubation period

Conlong *et al.* (1988) found that the incubation period *G. natalensis* on *E. saccharina* was 3 days. Witethom and Gordh (1994) noticed that the incubation period of *G. thailandensis* was 3.1 ± 0.0 days. Shoeb *et al.* (2005) studied the biology of *G. legneri* on three different host larvae and noted that the incubation period was shortest in *P. gossypiella* (1.64 ± 0.04 days) while it was longest in *Ephestia kuehniella* (Zeller) (1.80 ± 0.04 days).

Seetharama *et al.* (2007) reported that the incubation period of *A. sahyadrics* ranged from 2.00 to 5.00 days (Av. 3.08 ± 0.15 days). Landge *et al.* (2009) studied the comparative biology of *Bracon hebetor* Say on *Corcyra cephalonica* Stainton and *O. arenosella* and results showed that the incubation period of *B. hebetor* varied from 22.00 to 25.00 hrs and 23.30 to 26.00 hrs on *C. cephalonica* and *O. arenosella*, respectively.

Dabhi *et al.* (2013) conducted the biology of *B. hebetor* on seven lepidopteran hosts viz., rice moth, *C. cephalonica*, angoumois grain moth; *Sitotroga cerealella* (Olivier); greater wax moth, *Galleria mellonella* (Linnaeus); spotted pod borer, *Maruca testulalis* (Geyer); gram pod borer, *Helicoverpa armigera* (Hubner); tobacco leaf eating caterpillar, *Spodoptera litura* Fab.; and okra fruit borer, *Earias vittella* (Fabricius) under laboratory conditions. The results indicated that significantly shorter egg period (0.91 day) of *B. hebetor* was registered on *C. cephalonica* as compared to rest of the larvae used for rearing. Moreover, significantly prolonged egg period (1.68 days) was recorded in *S. litura* followed by *E. vittella* (1.63 days).

Malesios and Prophetou (2014) studied the development of the parasitoid, *B. brevicornis* on different larval instars (II to V instar larvae) of the Indian meal moth, *Plodia interpunctella* (Hubner). The results affirmed that the egg developmental period of *B. brevicornis* was 1.12 days on fourth instar larvae of *P. interpunctella*, while it was 1.18 days on fifth instar larvae.

Reda *et al.* (2014) studied the biological aspect of *B. brevicornis* when reared on different hosts (*E. kuehniella*, *G. mellonella*, *C. cephalonica*, *Sesamia cretica* Lederer, *S. littoralis* and *Pectinophora gossypiella* (Saunders)). The result suggested that the incubation period was prolonged in case *E. kuehniella* (39.87 ± 0.95 hrs) followed by *C. cephalonica* (36.69 ± 1.37 hrs) while it was shortest in *G. mellonella* (31.53 ± 1.22 hrs). Farag *et al.* (2015) studied the life table parameters of adults of *B. hebetor*, when reared on three different hosts viz., *G. mellonella*, *E. kuehniella*, and *C. cephalonica*. The results indicated that the incubation period of eggs was shortest in *C. cephalonica* (1.3 ± 0.053 days) followed by *G. mellonella* (1.33 ± 0.08 days), while it was prolonged in *E. kuehniella* (1.55 ± 0.097 days).

2.1.2 Larva

2.1.2.1 Colour, shape and size

Shoeb *et al.* (2005) studied the biology of *G. legneri* and found that three distinct larval instars of the parasitoid *G. legneri* were determined and early first instar larval was apodous hymenopterous form. The body of second larval instar was creamy in colour with movements of internal organs and the body of the third larval instar was yellowish. Seetharama *et al.* (2007) studied the biology of *A. sahyadrics* and result showed that the length of fourth instar larvae ranged from 3.28 to 8.58 mm (Av. 6.36 ± 0.22 mm) and width of fourth instar larvae varied from 1.00 to 1.43 mm (1.23 ± 0.02 mm).

Shah *et al.* (2014) observed that the morphometric characters of larva of *B. hebetor* and noticed that the length of *B. hebetor* were varied from 0.40 to 3.67 mm a mean of 1.69 mm. Moreover, the mean breadth of larva was ranged from 0.13 to 1.33 mm with a mean of 0.665 ± 0.07 mm.

2.1.2.2 Larval period

Kapadia and Mittal (1993) reported that the developmental period of *G. nephandidis* on *C. cephalonica* under laboratory condition. The larval period was shortest during June-July (4.0 days) as compared to other month (5.15 to 5.83 days). Witethom and Gordh (1994) found that the larval period of *G.thailandensis* was 4.1 ± 0.0 days. Shoeb *et al.* (2005) showed that the shortest larval duration of *G. legneri* exhibited in *E. kuehnniella* (2.20 ± 0.11 day) as against the longest in case of *P.gossypiella* (2.99 ± 0.12 days).

Seetharama *et al.* (2007) indicated that the total larval period of *A. sahyadrics* was 7.56 ± 0.12 days with a range of 5.83 to 8.00 days. Landge *et al.* (2009) studied the comparative biology of *B. hebetor* on *C. cephalonica* and *O. arenosella* and the results revealed that the total larval period ranged from 60.00 to 69.60 hours and 60.00 to 79.20 hours on *C. cephalonica* and *O. arenosella*, respectively. Hossein *et al.* (2012) found that the *Apanteles myeloenta* (Authority), a larval parasitoid of Carob moth, *Ectomyelais ceratoniae* (Zeller) and data revealed that the larval period of female wasps was 30.2 ± 0.34 days, 27.8 ± 0.44 days and 28.1 ± 0.47 days, while the corresponding parameters for males were 31.1 ± 0.51 days, 27.3 ± 0.3 days and 28.1 ± 0.24 days, respectively.

Dabhi *et al.* (2013) studied the biology of *B. hebetor* on seven lepidopteran hosts and found that the larval period was prolonged in *H. armigera* (3.84 days) followed by *M. testulalis* (3.42 days) and *G. mellonella* (3.33 days). The larval period was shortest in *C. cephalonica* (2.66 days) followed by *S. cerealella* (2.84 days).

Sreekanth and Muralimohan (2013a) indicated that the temperature had a significant influence on the male and female larval period of *G. nephandidis*. The total larval period for male and female individuals was 22.16 ± 1.59 and 24.95 ± 2.25 days for males and females, respectively at 34°C temperature while it was highest $41.22 \pm$

5.11 and 46.07 ± 4.52 days for males and females, respectively at 22°C temperature.

Reda *et al* (2014) studied the biological aspects of *B. brevicornis* when reared on different hosts and results showed that the mean duration of larval stage was significantly shorter on *S. cretica* (1.86 ± 0.079 days), while it was prolonged on *E kuehniella* (2.47 ± 0.53 days) and *C cephalonica* (2.44 ± 0.72 days). Malesios and Prophetou (2014) noticed the developmental period of *B. brevicornis* on different larval instars (II to V instar larvae) of the Indian meal moth, *P. interpunctella*. The results revealed that the larval period was 2.03 ± 0.06 days on fourth instar larvae and 1.68 ± 0.03 days on fifth instar larvae of host insect. Shah *et al.* (2014) reported that the biology of *B. brevicornis* affirmed that the mean larval duration was 3.17 ± 0.11 days and ranged from 2.4 to 4.0 days.

2.1.3 Cocoon

2.1.3.1 Colour, shape and size of cocoon

Gordh (1976) reported that the pre-pupa of *G. gallicola* was superficially resembles to the feeding larva except the cuticle was opaque and the spherules or urate cells were distinctly white in colour. The cocoon of *G. gallicola* was loosely woven white 5 mm in length and 1.5 mm in diameter. The cocoon constructions took 14 to 20 hours at 25°C temperature. Conlong *et al.* (1988) studied the biology of *G. natalensis* and results found that the pupal period lasted for about 10 to 14 days. Seetharama *et al.* (2007) studied the biology of *A. sahyadrics* and results emphasized that the pupae of male had 6.02 ± 0.16 mm in length while it was 1.25 ± 0.03 mm in width. Moreover, female pupa was 6.34 ± 0.18 mm in length and 1.30 ± 0.32 mm in width.

Shah *et al.* (2014) observed that the mean length of *B. hebetor* cocoon was 3.72 mm with a range of 3.3 to 4.1 mm. The minimum and maximum breadth of cocoon was 1.0 and 2.1 mm, respectively with a mean of 1.58 ± 0.079 mm.

2.1.3.2 Pre- cocoon period

Gordh (1976) reported that the pre- pupal period of *G. gallicola* was 3 to 5 days. Shoeb *et al.* (2005) showed that the shortest pre-pupal period of *G. legneri* recorded in *E.kuehniell* (0.73 ± 0.04 day) and the prolonged period was in *P. operculella* (0.84 ± 0.05 day). Landge *et al.* (2009) studied the comparative biology of *B. hebetor* and the results affirmed that the pre-pupal period was ranged from 0.40 to 0.50 day and 0.85 to 1.00 day on *C. cephalonica* and *O. arenosella*, respectively.

Dabhi *et al.* (2013) indicated that the pre-pupal period of *B. hebetor* was maximum (1.22 days) on *S. litura* followed by *H. armigera* (1.08 days). The significantly shorter duration of pre-pupa was registered in *C. cephalonica* (0.84 day) followed by *S. cerealella* (0.91 day). Malesios and Prophetou (2014) found that the pre- pupal period of *B. brevicornis* was 1.47 ± 0.08 days in fourth instar larvae while it was 1.29 ± 0.04 days in fifth instar larvae of *P. interpunctella*.

2.1.3.3 Cocoon (Pupal) period

Kapadia and Mittal (1993) reported that the pupal period was 6.56 and 10 days in January-February and May-June, respectively. Witethom and Gordh (1994) noted the pupal period of *G. thailandensis* was 13.5 ± 0.1 days. Venkatesan *et al.* (1990) showed that the storage of 48 hrs old cocoons of *G. nephantidis* at 15°C temperature for 10 days resulted in maximum adult emergence (90%), fecundity (84 eggs/female) and adults longevity (57 days/female). However, corresponding parameters were comparable with those cocoons kept at ambient temperature ($26 \pm 1^\circ\text{C}$) and it exhibited positive correlation with adult emergence and fecundity. However, adult emergence, fecundity and longevity were negatively correlated with storage periods at different temperature regimes viz., 5, 10 and 15°C under laboratory condition.

Shoeb *et al.* (2005) noted that the shortest pupal period of *G. legneri* was recorded in *E.kuehniell* (8.50 ± 0.49 days) and prolonged duration exhibited in case of *P.operculella* (9.33 ± 0.47 days). Landge *et al.* (2009) reported that pupal period of *B. hebetor* ranged from 4 to 5 days and 5 to 6 days on *C. cephalonica* and *O. arenosella*, respectively. Dabhi *et al.* (2013) studied the biology of *B. hebetor* on seven lepidopteran hosts and result indicated that the pupal period was shorter in *C. cephalonica* (3.71 days) followed by *S. cerealella* (3.86 days). Moreover, the pupal period was prolonged in *S. litura* (5.92 days) followed by *M. testulalis* (5.69 days) and *H. armigera* (5.06 days).

Reda *et al.* (2014) showed that duration of the pupae of *B. brevicornis* was prolonged on *P. gossypiella* (7.6 ± 0.13 days) compared to other hosts and it was shortest in *G. mellonella* (6.07 ± 0.23 days). Shah *et al.* (2014) recorded that the mean pupal duration of *B. brevicornis* ranged from 4 to 6 days (Av. 4.35 ± 0.15 days). Malesios and Prophetou (2014) found that the pupal period of *B. brevicornis* was 6.82 ± 0.09 days on fourth instar larvae while it was 7.76 ± 0.04 days on fifth instar larvae of *P. interpunctella*.

2.1.4 Total developmental period

Witethom and Gordh (1994) reported that the developmental period of *G. thailandensis* ranged from 16 to 26 days (Av. 20.7 ± 0.1 days). Shoeb *et al.*, 2005) recorded that the total developmental period of *G. legneri* was shortest in *E.kuehniell* (13.61 ± 0.61 days) and it was prolonged in case of *P. operculella* (14.83 ± 0.48 days). Redolfi and Campos (2010) laid out an investigation on the developmental and reproductive biology of the ectoparasitoid, *Elasmus steffani* (Viggiani) on a *E. kuehniella* and results revealed that the duration ranged from 11 to 15 days.

2.1.5 Adults

2.1.5.1 Colour, shape and size

Gordh (1976) indicated that the appendages of *G. gallicola* remain translucent within cocoon while tergites and sternites became black in colour at time of adult emergence and finally adult appeared as black in colour. Gordh and Witethom (1993) described new species of *G. thailandensis*, as a parasite of sapodilla (Sapota) fruit borer and results revealed that the body of *G. thailandensis* was predominantly black, antenna dusky yellow with apical segment with faintly light. The mandible black having ventral tooth dark to reddish brown. Coxae and femur had dark reddish brown; tibiae and tarsomeres had yellowish tan and tarsal claws black. Forewing exhibited weakly embrowned, costal and subcostal veins reddish brown and pterostigma was blackish and hind wings were hyaline. The female body length varied from 2.9 to 5.0 mm.

Seetharama *et al.* (2007) conducted experiment on the biology of *A. sahyadrics* and results exhibited that the males were winged, shiney metallic black in colour. The antennae were filliform and 13 segments with black in colour. The thorax was also black in colour and legs were dull white in colour. The size of the males ranged from 5.0 to 8.58 mm (Av.6.24 $\pm$ 0.19 mm) while width ranged from 0.86 to 1.72 mm. Moreover, the females were wingless and dark brown in colour. The antennae were filliform and having 13 segments with yellowish brown in colour. The females measured about 6.53 $\pm$ 0.18 mm in length with a range of 0.72 to 1.72 mm. The head, thorax and legs were yellowish brown in colour. The abdomen was broad, dark brown in colour.

Sreekanth and Muralimohan (2013b) observed the effect of female body size on the biological parameters of *G. nephantidis* and results affirmed that the head width of F₁ male and female adult parasitoids was maximum when produced by larger females (0.52 $\pm$ 0.02 mm in male and 0.86 $\pm$ 0.05 mm in female) as against adults

produced by smaller females had minimum head width (0.48 ± 0.05 mm in male and 0.78 ± 0.07 mm in female). The average head width of small and large parental female was 0.75 ± 0.05 mm and 0.90 ± 0.02 mm, respectively.

Shah *et al.* (2014) observed that the body length of *B. hebetor* female was larger than male. The length of male and female adult varied from 2.75 to 3.25 mm (Av. 3.015 ± 0.035 mm) and 3.0 to 4.0 mm (Av. 3.433 ± 0.066 mm), respectively. The breadth of adult male and female varied from 5.0 to 6.1 mm (Av. 5.457 ± 0.074 mm) and 5.0 to 6.2 mm (Av. 5.63 ± 0.069 mm), respectively.

2.1.5.2 Pre-oviposition period

Conlong *et al.* (1988) found that the pre-oviposition period of *G. natalensis* was 2 to 3 days. Witethom and Gordh (1994) reported that the pre-ovipositional period of *G. thailandensis* was 4.4 ± 0.4 days. Shoeb *et al.* (2005) recorded that the pre-ovipositional period of *G. legneri* on *E. kuehniella* larvae (2.60 ± 1.02 days) was shorter than the on *P. gossypiella* (3.13 ± 0.88 days).

Seetharama *et al.* (2007) found that the pre-ovipositional period of *A. sahyadrics* was 12.48 ± 0.63 days. Landge *et al.* (2009) studied the comparative biology of *B. hebetor* on *C. cephalonica* and *O. arenosella* and the results revealed that the pre-oviposition period ranged 11 to 19 hours and 15 to 20 hours on *C. cephalonica* and *O. arenosella*, respectively.

Redolfi and Campos (2010) recorded the mean pre-oviposition period of *E. steffani* was 8.9 ± 5.0 days on *E. kuehniella*.

Dabhi *et al.* (2013) reported that ovipositional period of *B. hebetor* on seven different hosts and results revealed that the pre-oviposition period was 0.64 to 0.86 day on different host larvae and there was no significant difference among the larvae of different hosts used. The relatively shorter pre-oviposition period was found in case of *C. cephalonica* (0.64 day) followed by *S. cerealella* (0.66 day).

Sreekanth and Muralimohan (2013a) studied the effect of temperature on the reproductive biology of *G. nephantidis* under laboratory condition. The results revealed that the time taken by the female parasitoid to begin egg laying on *O. arenosella* was least (4.20 ± 1.00 days) at 35°C and it was on par with those under 30°C (4.25 ± 0.63 days) followed by 4.90 ± 0.71 days at 25°C . However, female took more time at the lower temperature level of 20°C (7.50 ± 1.46 days).

Sreekanth and Muralimohan (2013b) studied the effect of female body size on the biological parameters of *G. nephantidis* and found that the pre-oviposition period of large sized female parasitoid was least (4.75 ± 1.21 days) as compared to smaller females (6.15 ± 1.53 days). Reda *et al.* (2014) recorded pre-oviposition period of *B. brevicornis* was 2.0 ± 0.21 and 1.71 ± 0.14 days for *C. cephalonica* and *G. mellonella*, respectively.

2.1.5.3 Oviposition period

Shoeb *et al.* (2005) recorded that the ovipositional period of *G. legneri* on *E. kuehniella* was longer (16.13 ± 0.88 days) as compared to *P. gossypiella* (14.93 ± 2.69 days). Seetharama *et al.* (2007) noted that the ovipositional period of *A. sahyadrics* was 2.74 ± 0.15 days.

Landge *et al.* (2009) studied the comparative biology of *B. hebetor* on *C. cephalonica* and *O. arenosella* and the results exhibited that the oviposition period ranged from 10 to 57 and 18 to 37 days on *C. cephalonica* and *O. arenosella*, respectively. Dabhi *et al.* (2013) indicated that the ovipositional period of *B. hebetor* significantly prolonged in *C. cephalonica* (28.41 days) as against shortest in *S. litura* (15.76 days).

Sreekanth and Muralimohan (2013b) reported that the oviposition period of *G. nephantidis* ranged from 22.80 ± 3.76 to 29.55 ± 5.24 days. Reda *et al.* (2014) recorded that the ovipositional period of *B. hebetor* on different hosts and results revealed that the

oviposition period was prolonged in *S. cretica* (16.8 ± 0.68 days) and shortest in *C. cephalonica* (10.4 ± 0.97 days).

2.1.5.4 Post oviposition period

Shoeb *et al.* (2005) recorded that the mean duration of the post ovipositional period of *G. legneri* on *E. kuehniella* larvae was 1.93 ± 1.23 days while it was shortest on *P. gossypiella* (2.20 ± 1.38 days). Landge *et al.* (2009) studied that the post- oviposition period of *B. hebetor* ranged from 1 to 9 days and 1 to 6 days on *C. cephalonica* and *O. arenosella*, respectively. Dabhi *et al.* (2013) recorded prolonged post-oviposition period of *B. hebetor* on seven different hosts was recorded in *Maruca testulalis* Geyer (5.38 days) followed by *G. mellonella* (4.81days). Sreekanth and Muralimohan (2013b) revealed that the post-oviposition period of *G. nepantidis* was prolonged in large sized females (12.15 ± 3.41 days) as against 10.45 ± 2.42 days in small sized females.

Reda *et al.* (2014) recorded that the post-oviposition period of *B. hebetor* for female parasitoid was prolonged when reared on *E. kuehniella* (1.9 ± 0.53 days) and shortest in *P. gossypiella* (0.78 ± 0.37 days)

2.1.5.5 Sex Ratio

Eylem and Adem (2005) conducted investigation on sex ratio of parasitoid *B. hebetor* in relation to parasitoid age reared on *G. mellonella*. The results revealed that the mean sex ratio (%female) were 45.99, 40.72 and 37.38 per cent in the 1, 5 and 10 day's age groups, respectively. Furthermore, the results of mean sex ratio (%female) of *B. hebetor* raised on *E. kuehniella* were 45.09, 40.68 and 36.09 per cent in the 1, 5 and 10 day's age groups, respectively.

Seetharama *et al.* (2007) reported that the sex ratio *A.sahyadrics* (M: F) was 1: 5. The sex ratio first, second and third brood was 1: 4, 1: 3 and 1: 2, respectively.

Landge *et al.* (2009) found that the sex ratio of *B. hebetor* (male: female) was 1.66: 1 and 1.30: 1 on *cephalonica* and *O. arenosella*, respectively under laboratory condition. According to Hossein *et al.* (2012), the sex ratio (females to males) of *A. myeloenta* was 1:3.5 for hosts parasitized in the first instar, 1:3 for second instar and 1:2 for third instar larvae of carob moth, *Ectomyelois ceratoniae* (Zeller). Moreover, the total number of emerged adults was 153, 526 and 378 from first, second and third host larval instar stages, respectively.

Sreekanth and Muralimohan (2013a) observed that the sex ratio of the progenies produced was not significantly differed at the temperature 25⁰ C and 35⁰ C temperature (0.11 and 0.10 males, respectively). Later on, at 20⁰ C temperature, the sex ratio was found to be slightly male biased (0.14 males) and male dominated progeny was produced (0.28 male).

Sreekanth and Muralimohan (2013b) noted that the sex ratio of *G. nephantidis* progenies produced by small sized female *G. nephantidis* was highest (0.20 males) when compared to 0.13 males produced by large sized females. Dabhi *et al.* (2013) recorded sex ratio (Female: Male) of *B. hebetor* reared on different host larvae revealed that sex ratio was minimum in case of *C. cephalonica* (1: 1.32) and it was highest on *S. litura* (1: 1.77).

Hegade *et al.* (2014a) study revealed that the sex ratio of *G. nephantidis* (Male: female) on larvae of *C. cephalonica* reared on different rearing media was female biased *i.e.* the highest numbers of females were observed in treatment of sorghum (750 g) + Groundnut (250 g) + Yeast (5 g) + Sugar (5 g) had 1:27.75. Hegade *et al.* (2014b) investigated the effect of *Goniozus* adult nutrition under laboratory condition and results revealed that the maximum females were produced in the treatment of fructose 50 per cent.

2.1.5.6 Adult longevity

Gordh (1976) observed that the mean longevity of mated *G. gallicola* female was 62.43 ± 8.48 days. Conlong *et al.* (1988) noted that the *G. natalensis* males lived for period of 6.1 ± 2.8 days and females for about 13.1 ± 1.26 days. Witethom and Gordh (1994) studied the developmental period of *G. thailandensis* under laboratory condition. The results revealed that the longevity of mated females provided with host was 7.2 ± 0.6 days and mated host-deprived females lived for about 7.7 ± 0.5 days. While, in case of the mean longevity of mated males provided with host was 5.7 ± 0.6 days for mated males and 7.7 ± 0.4 days for mated host-provided females.

Shoeb *et al.* (2005) studied the biology of *G. legneri* and the results showed that the longevity of male shorter than the female. The mean mated adults longevity were 1.67 ± 0.70 and 2.67 ± 0.70 days in males for starved and honey solution feeding diets, respectively. Moreover, the longevity of unmated male on the same diets lasted for about 1.53 ± 0.72 and 2.33 ± 0.70 days, respectively. The corresponding parameter of the mated females were 6.73 ± 1.53 and 15.20 ± 2.04 days at starved and honey solution feeding adults, respectively; while it was 6.00 ± 1.46 and 15.20 ± 2.10 days for the unmated females, respectively.

Seetharama *et al.* (2007) revealed that the female of *A. sahyadrics* lived for a period of 66.48 ± 3.66 days on with a range of 11 to 128 days. In case of male, the average longevity was 7.96 ± 0.30 days with a range of 5 to 15 days. Landge *et al.* (2009) indicated that comparative biology of *B. hebetor* on *C. cephalonica* and *O. arenosella* and the results revealed that female and male longevity of *B. hebetor* was ranged from 14 to 59 and 6 to 22 days; and 10 to 32 and 6 to 20 days on *cephalonica* and *O. arenosella*, respectively.

Redolfi and Campos (2010) studied the adult's longevity of *E. steffani* on different food sources viz., without food, honey-water and honey-water along with host larvae. The results revealed that the

significantly prolonged adult longevity was honey-water food source (88.5 ± 16.4 and 32.6 ± 7.4 days) followed by honey-water along with host larvae (88.5 ± 16.4 and 15.4 ± 6.0 days), without food (2.3 ± 0.7 and 2.2 ± 0.7 days) female and male, respectively.

Sreekanth and Muralimohan (2013a) recorded the male and female longevity of *G. nephantidis* and found that the longevity was prolonged at 20°C (21 and 24.35 days for male and female, respectively) whereas shortest longevity at 35°C (13.50 and 14.20 days for male and female, respectively). Sreekanth and Muralimohan (2013b) revealed that the longevity of the large size female was prolonged (41.90 ± 5.86 days) and small sized female was shortest (38.40 ± 4.58).

Dabhi *et al.* (2013) revealed that the shorter and prolonged male longevity of *B. hebetor* was on *S. litura* (5.09 days), *C. cephalonica* (9.33 days), respectively. Moreover, female was shorter and prolonged on *S. litura* (16.02 days) and *C. cephalonica* (31.76 days) respectively. Hegade *et al.* (2014a) studied the parasitic potential of *G. nephantidis* on larvae of *C. cephalonica* reared on different rearing media and the data revealed that the adult longevity was superior (35.20 days) in the treatment of wheat flour (750 g) + ground rice (250 g) + sugar (5 g).

Hegade *et al.* (2014b) investigated the effect of adult nutrition on parasitization potential of *G. nephantidis* under laboratory condition results indicated that, treatment of honey solution was best suitable and effective treatment (26.25 days) as compared to other treatments. Reda *et al.* (2014) found that the shorter and prolonged male longevity of *B. hebetor* was on *E. kuehniella* (15.73 ± 0.7 days), *C. cephalonica* (11.75 ± 0.51 days), respectively. The female shorter and prolonged period was on *S. cretica*, (19.6 ± 0.51 days), *C. cephalonica* (13.5 ± 1.02 days), respectively.

Shah *et al.* (2014) reported that the adult's longevity of *B. hebetor* revealed that the female longevity was 20.00 ± 0.865 days and

ranged from 15 to 29 days, in case of male longevity was 14.40 ± 0.638 days and ranged from 8 to 20 days. Farag *et al.* (2015) revealed that the prolonged and shorter female longevity of *B. hebetor* was on *G. mellonella* (19.11 ± 1.8 days), *C. cephalonica* (9.7 ± 0.71 days), respectively. Moreover, prolonged and shorter male longevity was on *G. mellonella* (9.2 ± 0.66 days), *E. kuehniella* (7.6 ± 0.6 days) respectively.

2.1.5.7 Fecundity/Clutch size

Dharmaraju (1952) reported that single female laid about 10 to 14 eggs per day. Paul *et al.* (1979) observed the maximum egg laying of parasitoid was 12 eggs per host. Witethom and Gordh (1994) revealed that the brood size of *G. thailandensis* was 2 to 13 larvae per host. Mohan and Shameer (2003) results showed that the clutch size of *G. nephandidis* was 11.56 ± 2.29 , 10.30 ± 2.91 and 10.00 ± 2.40 on *O. arenosella*, *C. cephalonica* and *G. mellonella*, respectively.

Shoeb *et al.* (2005) found that fecundity of *G. legneri* ranged from 42.07 ± 1.38 on *P. gossypiella* to 44.67 ± 10.59 on *E. kuehniell.* Seetharama *et al.* (2007) results exhibited that the female of *A. sahyadrics* laid 53.64 ± 3.06 eggs (Av. 10 to 123 eggs). The clutch size ranged from 3 to 35 eggs per host larvae (Av. 17.52 ± 1.11). Landge *et al.* (2009) noted that the fecundity of *B. hebetor* was ranged 141 to 577 and 13 to 59 on *cephalonica* and *O. arenosella*, respectively. Redolfi and Campos (2010) counted the number of eggs laid by *E. steffani* per host larva and it was 4.4 ± 0.4 with a range of 1 to 29 eggs per host. Dabhi *et al.* (2013) reported that the maximum and minimum fecundity of *B. hebetor* was recorded on *C. cephalonica* (154.25 eggs) *S. litura* (73.63 eggs), respectively with a range of 109.12 to 132.90 eggs/ female.

Sreekanth and Muralimohan (2013b) noted that the large sized parasitoid laid 89.15 ± 7.63 eggs as compared to small sized females deposited less number of eggs (66.50 ± 9.52). Reda *et al.* (2014) revealed that the fecundity of *B. brevicornis* was more on *G.*

mellonella (268.88 ± 19.65 eggs) and less on *E. kuehniella* (71.1 ± 7.15 eggs). Malesios and Prophetou (2014) results indicated that the mean number of eggs laid by *B. brevicornis* on fourth instar larvae of *P. interpunctella* was 2.42 eggs per adult, while on fifth instar larvae; it was 13.65 eggs per adult. In case of the second and third instar larva of *P. interpunctella* was 4 and 13 eggs, respectively.

According to Farag *et al.* (2015), the total eggs deposited by *B. hebetor* was highest on *G. mellonella* (395.11 ± 79.7 eggs) and it was least on *C. cephalonica* (56.0 ± 6.3 eggs).

2.1.6 Total life cycle

According to Seetharama *et al.* (2007), the total life cycle of *A. sahyadrics* was completed within 31.36 ± 0.67 days (22 to 42 days). Landge *et al.* (2009) noted that the life cycle *B. hebetor* completed within 8.25 and 10.56 days on *C. cephalonica* and *O. arenosella*, respectively. Dabhi *et al.* (2013) reported that the shortest and prolonged life-cycle (egg to adult) of *B. hebetor* female was on *S. litura* (27.64 days), *C. cephalonica* (44.30 days), respectively. While in case of male, it was shortest and prolonged on *S. litura* (8.72 days) and *C. cephalonica* (15.28 days), respectively.

2.2 Parasitic potential of *G. nephantidis* on *C. cephalonica*.

Pillai and Bhat (1986) found that the stage of the host larvae used was critical to determining the host acceptance of *G. nephantidis*, number of eggs laid, and number of offspring developed and the proportion of males in the brood of *G. nephantidis*. Further, indicated that 5th and 6th instar larvae of *O. arenosella* were ideal for successful parasitization and large scale multiplication of *G. nephantidis* under laboratory condition.

Conlong *et al.* (1988) revealed that the mean larval parasitism of *G. natalensis* was 18 per cent and the number of *G. natalensis* females successfully parasitized on host larvae was averaged about 36 per cent. Witethom and Gordh (1994) reported that the mean number of host larvae parasitized by female *G. thailandensis*

was 1.6 ± 0.1 with 13.3 ± 1.2 per cent. Venkatesan *et al.* (2004) studied the life-table and intrinsic rate of *G. nephantidis* on three lepidopteran host insects viz., *O. arenosella*, *C. cephalonica* and *G. mellonella* under laboratory conditions. The results noted that highest net reproductive rate was obtained on *C. cephalonica* (42.6 females/female) followed by *O. arenosella* (38.2 females/female) and *G. mellonella* (28.8 females/female). The intrinsic rate of increase and weekly multiplication rate were also highest on *C. cephalonica* - followed by *O. arenosella* and *G. mellonella*.

Dhiman and Pooja (2005) reported that the percentage of parasitization by *Bracon* sp. on *Pauropsylla depressa* Crawford ranged from 5 to 40 per cent during July to October. Shueb *et al.* (2005) concluded that the total number of paralyzed host larvae by the female of *G. legneri* was 22.67 ± 4.01 for *E. kuehniella* and 22.20 ± 4.23 for *P. gossypiella* larvae. The total number of parasitized host larvae by *G. legneri* was 8.67 ± 2.10 on *E. kuehniella* larvae and 7.80 ± 2.10 on *P. gossypiella* larvae.

Venkatesan *et al.* (2009a) reported the survival of *G. nephantidis* and *B. brevicornis* under laboratory condition. The survival of *G. nephantidis* was 86.8 per cent and females chased *B. brevicornis* females, attempted to bite and sting to the host. The mean percentage of progeny obtained was significantly higher in *G. nephantidis* than *B. brevicornis*. Moreover, *G. nephantidis* dominated due to its parental care behavior by producing 87.0 per cent of progeny with better sex ratio (1: 0.79), whereas *B. brevicornis* produced 84.0 per cent with normal progeny and a sex ratio (1:0.36).

Venkatesan *et al.* (2009b) investigated that the influence of different densities of *G. nephantidis*, its host *C. cephalonica* and results indicated that the maximum parasitism (9.0 larvae/female), fecundity (93.2/female) and number of progenies (75.2/female) was recorded with host- parasitoid ratio (1:1). Furthermore, more than one *C. cephalonica* larvae exposed to *G. nephantidis* did not increase

the parasitizing efficiency, fecundity and progeny produced. Conversely, exposing a single *C. cephalonica* larva to several female parasitoids adversely affected the biological attributes of the parasitoid. Sathe and Chougale (2009) found that the rate of parasitization by *Dolichogenidea mythimna* Sathe and Bhoje on *Mythimna separata* was higher (94 % and 76 %) with 5 and 10 parasitoid density but reduced considerably with density 1, 15 and 20 (6%, 70% and 74%, respectively). According to Redolfi and Campos (2010), the number of parasitized host's larvae per day by *E. steffani* was 1.3 ± 0.1 with a range of 1 to 4 larvae per day.

Akbarzadeh (2012) reported that the per cent of parasitism by larval parasitoid complex and results revealed that six larval parasitoids of the host were reported viz., *Enytus apostata* Gravenhorst, *Pristomerus vulnerator* (Panzer), *Temelucha* sp., *Nemorilla maculosa* (Meigen) *Habrobracon hebetor* (Say) and *Bracon* sp.) on Grape berry moth, *Lobesia botrana* (Denis and Schiff.) The parasitism was varied from 1 to 16.8 per cent (Av. 7.7%).

Hegade *et al.* (2014a) studied the parasitic potential of *G. nephantidis* on larvae of *C. cephalonica* reared on different rearing media and the data revealed that the maximum number of larvae paralyzed by the female exhibited in treatment of sorghum (750 g) + kidney bean (250 g) + sugar (5 g) was 7.00 larvae per female. Hegade *et al.* (2014b) revealed that there was no any effect of food on parasitization of number of *Corcyra* larvae by *G. nephantidis*.

Alam *et al.* (2015) studied the generation-wise parasitizing efficiency of mass reared *B. hebetor* on wax moth and the results revealed that the in the first experiment; per cent parasitization by *B. hebetor* at first generation collected from the caged micro plot on the host *G. mellonella* larvae did not vary significantly with the progress of generations However, parasitisation efficiency was more or less similar up to 5th generation (80%) and decreased sharply from 6th generation showing the lowest parasitization at 6th generations. In the

second experiment; generation wise parasitization by *B. hebetor* reared in laboratory ranged between 55 to 95 per cent. Significantly highest per cent parasitisation was recorded from first generation (95%) followed by third (80%) and fourth (72%) generations. The lowest parasitization was found in sixth generation (55%).

Neam *et al.* (2015) investigated the parasitic potential of *B. hebetor* on *G. mellonella* and reported that the complete paralysis of the host larva within 10 to 15 minutes. The number of *G. mellonella* larvae attached by honey fed female parasitoid was 24.6 ± 1.78 at the density of 3 larvae to 48.1 ± 1.42 at density of 10 larvae.

2.3 Relative toxicity of various insecticides against *G. nephantidis*.

Sundaramurthy (1980) revealed that diflubenzuron was applied once at 2.5-20 g a.i./ 10 litres of water to coconut palms infested with larvae of *Nephantis serinopa* Meyr. The percentage of normal adults produced from treated parasite larvae ranged from 17.3 to 43.0 per cent as against 99.1 per cent from untreated larvae.

Bhushan and Azam (1990) studied the toxicity of fenvalerate, permethrin, cypermethrin and deltamethrin to the bethylid *P. nephantidis* [*G. nephantidis*] and *B. hebetor*, parasitoids of *O. arenosella* under laboratory condition. The results showed that deltamethrin was the most toxic insecticide to both parasitoids with LC_{50} of 0.0000926 and 0.0000626 per cent for *G. nephantidis* and *B. hebetor*, respectively. It was followed by cypermethrin (0.000107 and 0.0000693%), permethrin (0.000284 and 0.000820%) and fenvalerate (0.000505 and 0.000126%).

Patil *et al* (1990) showed that monocrotophos and chlorpyrifos were toxic to all stages of *G. nephantidis* and *B. brevicornis*. The tolerance of the parasitoids to the pesticides increased with age, as eggs were the most vulnerable stage to the insecticides application under laboratory condition. Dhawan (2000) studied some new insecticides on natural enemy complex of cotton

ecosystem. The results revealed that the Delfin (1000 g.a.i. /ha) was safer to larvae of *C. carnea* followed by leufenuron (60 g.a.i./ha), fluofenuron (75 g.a.i./ha) and methozoid (343 g.a.i./ha). Whereas, quinalphos (500 g.a.i./ ha), chlorpyriphos (1000 g.a.i./ha) and chlorpyriphos methyl (1000 g.a.i./ha) were found more toxic to the larvae of *C. carnea* recorded 90.7 to cent per cent mortality of the larvae.

Katole and Patil (2000) reported that the seed treatment was safe to the adults of *C. carnea* than the foliar spray and reported that thiamethoxam 4 g/kg seed and imidacloprid 8 g/kg seed (lower doses) were safer for the female of *C. carnea*. Srinivasan and Sundarababu (2000) found that the abamectin (0.003 %) proved to be safer pesticide for larvae of *C. carnea* as compared to carbaryl (0.1 %), quinalphos (0.05 %) and monocrotophos (0.072 %). Consoli *et al.* (2001) evaluated efficacy of different insecticides to *T. chilonis* and found that the lufenuron (15 g a.i./100 l water), triflumuron (25 g a.i./100 l water) and spinosad (48 g a.i./100 litre water) were harmful and tebufenozide (12 g [a.i.]/100 litre water) was harmless to *T. galloi*.

Rajamanickam and Natarajan (2002) conducted field experiment on root feeding of biopesticide Azadiractin F5% @ 10ml +10ml water and inundative release of larval parasitoids *B. brevicornis* , *G. nephantidis* and pupal parasitoid *T. pupivora* were made at 21 days intervals for each treatment in two phases. The results revealed that estimated mean pest population per palm was significantly reduced from 785.60 to 210.50 palms at 21 days after 1st root feeding of biopesticide. Furthermore, it reduced from 210.50 to 48.20 per palm at 21 days after the 1st release of parasitoid. The maximum reduction of *O. arenosella* was observed from 11.45 per palm to 4.35 per palm at 21 days after the completion of 2nd phase of Azadiractin F5 treatment and release of parasitoid. Therefore, the population build up for all the three parasitoids exhibited 3.65 per

cent, 2.80 per cent and 1.465 per cent to 29.40 per cent, 16.96 per cent and 6.65 per cent, respectively.

Abida *et al.* (2004) investigated that the efficacy of different insecticides to *C. carnea* and *Trichogramma chilonis* Ishii semi-field conditions and revealed that the out of nine insecticides tested, the *Bacillus thuringiensis*, spinosad, thiodicarb and indoxacarb exhibited selectivity for beneficial insects, particularly for *C. carnea* and insecticides *viz.*, chlorfenapyr and cypermethrin were also found selective for *C. carnea* but toxic for *T. chilonis*. The profenofos was found toxic to both the beneficial insects.

Varghese and Beevi (2004) studied the safety of insecticides to the *Chrysoperla carnea* Stephens under the laboratory condition. The result revealed that chlorpyrifos recorded the lowest LC₅₀ value i.e. 0.0017 and found to be the most toxic to the larvae of *C. carnea*. Moreover, the other insecticides tested in the decreasing order of toxicity were profenofos (0.0028) > malathion (0.0038) > trizophos (0.0349) > acephate (0.0491) > acetamiprid (0.0515) > imidacloprid (0.0997).

Rashad *et al.* (2005) investigated that the toxicity of two conventional insecticides chlorpyrifos 40 EC, profenofos 50 EC, and three new chemistry insecticides lufenuron 5 EC, emamectin benzoate 1.9 EC and methoxyfenozide 25 SC to assess the mortality of newly emerged adults of *B. hebetor* and observed 12, 24, 36 and 48 hours after treatment with different insecticides at different dose rates, results revealed that the all insecticides gave significant mortality of adult parasitoids as compared to the untreated check. chlorpyrifos and profenofos were found to be the most toxic for the parasitoid at their different doses after 36 hours of exposure. Complete mortality of the adult parasitoid was observed in chlorpyrifos with all doses (900, 1000, 1100 ml/acre) after 36 hrs of exposure. The emamectin benzoate was found to be the least toxic for all of its doses (90, 100, 110 ml/acre) used in this experiment even after 48 hours of exposure.

However, methoxyfenozide and lufenuron were found to be moderately toxic with their recommended doses (100 ml and 50 ml/acre, respectively) after 24 and 36 hours of exposure. However, their higher doses (110ml and 55ml/Acre, respectively) gave complete mortality after 48 hours.

Sunithadevi *et al.* (2006) reported that dimethoate (0.025 %) and cypermethrin (0.005 %) were found to be least toxic to the larvae and adults of *C. carnea*. Nalini and Manickavasagam (2011) conducted the experiment for safety of selected insecticides to mealybug parasitoids, *Aenasius bambawalei* (Hayat) and *Aenasius advena* (Compere) (Hymenoptera: Encyrtidae) was evaluated by using dry film method at 1, 3, 6, 12, 18 and 24 hours after treatment (HAT). The results revealed that the per cent corrected mortality of *A. bambawalei* and *A. advena* due to various insecticides were used, endosulfan, monocrotophos, profenofos and dimethoate caused 100 per cent mortality within 1 hour in both *A. bambawalei* and *A. advena*, which was significantly higher than untreated check. Imidacloprid was comparatively safer and caused 100 per cent mortality of both the sexes of the parasitoids after 3 hours. However, nimbecidine caused 100 per cent mortality only after 24 hours indicating that it is the safest of all the insecticides tested for both the parasitoids.

Ahmad *et al.* (2012) concluded that the spinosad (0.2, 0.15, 0.1, 0.05 and 0.01%) was found highly toxic for the adults *T. chilonis*, while it was less toxic to the parasitoid in oviposition preference. Dang and Takatoshi (2012) experiment conducted on toxicity insecticides to *Neochrysocharis okazakii* (Kamijo) (Hymenoptera: Eulophidae), a larval parasitoid leaf miners (*Liriomyza*) on vegetables. The results found that the different degrees of toxicity to the parasitoid LC_{50} values were 0.0035, 8.779, 0.0508, 0.0085 and 0.0231 mg a.i./lit and recommended field rate 25, 62.5, 6.25, 50, 25 g ai/ha for imidacloprid, pymetrozine, lufenuron, ethofenprox and

clothianidin, respectively. Based on risk quotient, imidacloprid and enthofenprox were highly toxic. The treatment of pymetrozine was harmless to *N. okazakii* while lufenuron and clothianidin were slightly to moderately toxic to the parasitoid.

Hooshang *et al.* (2012) investigated the sub lethal effects of indoxacarb, imidacloprid and deltamethrin on life table parameters of *H. hebetor* (Hymenoptera: Braconidae). The pupae were treated with aqueous solutions of field recommended doses of imidacloprid, indoxacarb and deltamethrin by topical method (290, 125, and 83 ppm based on active ingredient, respectively). The results indicated that the significantly lowest gross reproductive rate was detected in deltamethrin (112.06 ± 11.87) and the highest gross reproductive rate value was on control (204.62 ± 13.97). However, it was not significantly influenced by imidacloprid (207.67 ± 29.63) and indoxacarb (209.09 ± 24.71) compared to control.

Vahid (2013) studied the effects of field recommended concentrations of seven biorational and conventional pesticides used in cotton ecosystem viz., imidacloprid SC 35, thiacloprid SC 48, deltamethrin EC 2.5, thiodicarb EC 1.8, carbaryl WP 85, abamectin EC 1.8 and spinosad SC 24 on the larval ectoparasitoid, *H. Hebetor*. The results showed that synthetic and biorational pesticides had lower toxicity than conventional pesticides. The treatment of imidacloprid and thiacloprid had lower adverse effects on cumulative mortality of parasitoid adults exposed to pesticides at 12 hrs (8.89 ± 4.84 and $26.67 \pm 5.09\%$), 24 hrs (10 ± 5.77 and $28.89 \pm 4.84\%$), 36 hrs (13.33 ± 3.33 and $32.22 \pm 4.84\%$) and 48 hrs (14.44 ± 2.94 , $34.45 \pm 6.19\%$), respectively.

Chaturvedi (2014) carried out investigation to determine the relative toxicity of nine commonly used insecticides viz., cypermethrin 25% EC, endosulfan 35% EC, carbaryl 5% DP, cyhalothrin 5% EC, phosalone 35% EC, deltamethrin 2.8% EC, monocrotophos 36% SL, thiodicarb 75% WP, and chlorpyrifos 50%

EC against larval parasitoid *Carcella illota* (Curran) under the laboratory conditions. The result indicated that the thiodicarb and phosalone were least toxic; deltamethrin, chlorpyrifos, cypermethrin and monocrotophos were slightly harmful, carbaryl and cyhalothrin were most toxic to *C. illota*.

Essam *et al.* (2014) carried out laboratory bioassays to evaluate the effectiveness of two Insect Growth Regulators (IGRs); flufenoxuron and lufenuron on *S. littoralis* and their safety on natural enemies through studying the direct and indirect toxicity on the egg parasitoid, *Trichogramma evanescens* Westwood and the larval parasitoid *B. brevicornis*. The results indicated that the flufenoxuron has more indirect toxicity than Lufenuron. Parasitism rate, adult emergence and adult longevity of *T. evanescens* and *B. brevicornis* were decreased with flufenoxuron than treated by lufenuron. The results suggest that lufenuron is a potentially compound for controlling *S. littoralis*.

Dilbar *et al.* (2015) reported that the emamectin benzoate, lufenuron, triflumuron 20 SC and imidacloprid 200 SL were found safer to *T. chilonis* and recorded more than 50 per cent adult emergence. Karthik *et al.* (2015) Laboratory experiments were conducted to study the safety of emamectin benzoate 5 SG to the egg-larval parasitoid, *C. blackburni*, that adult mortality increased gradually at different interval in all the insecticidal treatments and all the insecticides were toxic to *C. blackburni*. The least mortality of *C. blackburni* adults was observed in the lower dose of emamectin benzoate 5 SG (7 g a.i./ha) which showed 13.33, 23.33 and 33.33 per cent mortality at 6, 12 and 24 HAT, respectively, while the recommended dose of emamectin benzoate 5 SG (11 g a.i./ha), emamectin benzoate 5 SG (11 g a.i./ha), and emamectin benzoate (9 g a.i./ha) recorded the per cent adult mortality of 23.33, 33.33 and 43.33 at 6 HAT, respectively, 26.67, 36.67 and 46.67 at 12 HAT, respectively and 16.33, 26.67 and 40.00 at 24 HAT, respectively.

Among the emamectin benzoate 5 SG treatments, the highest mortality was accounted at 15 g a.i. per ha to the extent of 36.33, 40.00 and 50.00 per cent at 6, 12 and 24 HAT, respectively. While the standard checks, spinosad at 75 g a.i.ha⁻¹ registered the mortality percentage of 36.67, 46.67 and 56.67 at 6, 12 and 24 HAT, respectively.

Fariba and Effat (2015) investigated the toxicity of selected insecticides on different developmental stages of the egg parasitoid *Trichogramma brassicae* (Bezdenko) under the laboratory conditions. The results of the tests revealed that imidacloprid and chlorpyrifos were the most harmful insecticides to larvae. The lowest emergence rate occurred with cypermethrin (4.50±1.04) and chlorpyrifos (0±0) at pupal stage treatment. Furthermore, the results of assessing the toxicities of different pesticides on *T. brassicae* adults, all the tested pesticides caused high mortality to adult parasitoids at 96 hours after application, imidacloprid (96.39 per cent) and chlorpyrifos, cypermethrin (100 per cent) were highly toxic to *T. brassicae*. Moreover, all pesticides were moderately persistent except chlorpyrifos classified as persistent.

2.4 Natural occurrence of larval parasitoid of black headed caterpillar under Navsari condition.

Farrugia (1981) reported the occurrence *G.antipodum* was redescribed and 3 species viz., *G.jacinta* sp.n., *G.collessis* sp.n. and *G.mandibulatus* sp.n., from the females, figured and keyed. All are from Australia, and *G. jacintae* and *G. mandibulatus* are parasites of the tortricid *Epiphy aspostvittana* (Wlk.). Manjunath (1985) reported severe outbreaks of *O. arenosella* on coconut in several parts of Karnataka and Andhra Pradesh in the year 1983 to 1984. The larval parasitism by *G. nephantidis* was 28 per cent on *O. arenosella*. Vyas and Butani (1986) identified the indigenous parasites of the *O. arenosella*, a pest of coconut from field collections of larvae and pupae of the pest and parasite cocoons in Gujarat, India, during 1978-80. Moreover, *B. brevicornis* and *G. nephantidis* were found to

parasitize larvae of the pest, the rates of parasitism reached to 12.2 per cent in June and 7.9 per cent in May, respectively. Kapadia and Mittal (1993) studied the activity of *Perisierola nephantidis* Mues. in coconut plantation and reported that the maximum parasitism by *P. nephantidis* was 5.98 per cent in November (1980-81) followed by 5.75 per cent in February (1981-82). The average parasitization of *P. nephantidis* throughout four years was maximum in February (3.66%) followed by November (3.20 %) and the activity of the parasitoid was low in May (1.04 %).

Gubbaiah and Revanna (1989) conducted survey on natural enemies of *O. arenosella* in coconut plantation during 1981-83 and it was concluded that larval parasitoids *B. brevicornis* and *P. nephantidis* [*G. nephantidis*] and pupal parasitoids *Brachymeria* spp. naturally occurred on *O. arenosella*. Pillai and Nair (1995) noted that the about 40 species of parasitoids were recorded in association with the coconut caterpillar, *O. arenosella*, in India and Sri Lanka. Apart from the dominant tachinid parasitoid, *Stomatomyia bezziana* (Baronov), all other species were prevalent in India. Among these, only seven species of parasitoids viz., *B. hebetor*, *B. brevicornis* and *G. nephantidis* attacking the larvae, *E. nephantidis* attacking pre pupae and *Tetrastichus israeli* Mani and Kurian, *Trichospilus pupivorus* Ferriere, and *T. diatraeae* were gregarious in nature.

Pushpalatha and Veeresh (1995) conducted survey in 20 year old coconut plantation in Bangalore, Karnataka and revealed that the population of *O. arenosella* was present throughout the year, reaching peak during March to May and lower during September to December. The three species of natural enemies recorded viz., *G. nephantidis* and *A. taragamae*, and the carabid predator *Parena nigrolineata* (Chaudoir) and these natural enemies did not play a significant role in regulating the pest population.

Desai *et al.* (2003) reported that the high percentage of parasitism of *G. nephantidis* was observed during throughout year.

The pest intensity was decreased from June onwards and the intensity was very low in July-September. Lyla and Beevis (2003) observed the occurrence of the coconut black-headed caterpillar, *O. arenosella*, and its natural enemies during the dry months (January-May) in Thrissur, Kerala, India. The peak incidence of *O. arenosella* densities was recorded in March, during which the percentage of leaf infestation was 51.34 per cent at Irinjalakkuda and 42.94 per cent at Ayyanthole. The leaf infestation level decreased in May to 34.06 and 38.73 per cent at Irinjalakkuda and Ayyanthole, respectively.

Abbas and Salwa (2006) survey revealed that the three parasitoids were found to attack on the larvae of the potato tuber moth, *Phthorimaea operculella* (Zeller) viz., *Apanteles litae* var. *operculellae* Nixon, *Diadegma molliplum* Himgrn. and *B. instabilis*. The total percentages of parasitism by the three parasitoids on *P. operculella* ranged from 11 to 28.6 per cent in February-May months with an average of 19.1 per cent. The larvae of *P. operculella* infesting tomato leaves were found to be parasitized by only the *B. instabilis*. The percentages of parasitism ranged from 0.0 to 21.4 per cent with an average of 11.1 per cent. The peak parasitism (21.4) was noticed in October.

Gongoklim and Seunghwan (2006) reported five species of *Goniozus* on *O. arenosella* in Korea viz., *Goniozus koreanus* Lim, sp. nov., *G. mesolevis* Lim, sp. nov., *G. akitsushimanus* Terayama, *G. yoshikawai* Terayama and *G. maurus* Marshall. Among them, *G. akitsushimanus* Terayama, and *G. yoshikawai* Terayama, were newly recorded (2006) from Korea.

Deen and Bhagat (2009) conducted field survey in Kashmir Valley (India) during 2004-2006, to determine the parasitoids associated with insect pests of cruciferous crops, the two butterfly pests, viz., *Pieris rapae* (Linnaeus) and *Pontia daplidice* (Linnaeus) were found attacking cruciferous crops. The rearing of larvae and pupae of *P. rapae* noted three parasititoids, viz., *Cotesia glomerata*

(Linnaeus) (Braconidae), *Hyposoter ebeninus* (Gravenhorst) (Ichneumonidae) and *Brachymeria femorata* (Panzer) (Chalcididae). However, only *H. ebeninus* was recovered from *P. daplidic*. The highest extent of parasitism 28 per cent and 22 per cent caused to its host pests, *P. rapae* and *P. daplidice*, respectively.

Sujatha and Chalam (2009) undertook random and roving survey from the year 2003 to 2006 to know the incidence of coconut black headed caterpillar and to estimate natural enemy fauna in four major coconut growing districts of Andhra Pradesh. The results revealed that the release of larval parasitoid *G. nephantidis* laid down pest population from 16.73 to 8.73 per palm with 30 per cent parasitization. Shivanand and Deshapande (2011) reported that the activity period of larval parasitoid, *Goniozus sp.* observed from second week of August to second week of November. The peak parasitization of *Goniozus sp.* was observed (17.50%) during the first week of October. Tanwar *et al.* (2011) field survey indicated that the *Aenasius bambawalei* (Hayat) (Chalcidodea: Encyrtidae) an indigenous parasitoid on *Phenacoccus solenopsis* (Tinsley) played a key role in reducing the insect pest infestation.

Anand and Sujata (2013) found that the *Apanteles sp.* was recorded as ecto - larval parasitoid whereas *Bracon sp.* was found as pupal parasitoid of the pod fly, *Melanagromyza obtusa* (Malloch) and *Apanteles sp.* was found in the first week of February with 2.00 per cent parasitism and it was increased up to 6.47 per cent by the end of February. The maximum 21.17 and 11.39 per cent parasitism was recorded in the IV week of February for the major parasitoids, *Euderus lividus* (Eulophidae), and *Ormyrus orientalis* (Ormyridae), respectively; *Bracon sp.* appeared for the first time in the first week of December. The parasitism increased from 1.92 to 7.40 per cent during December.

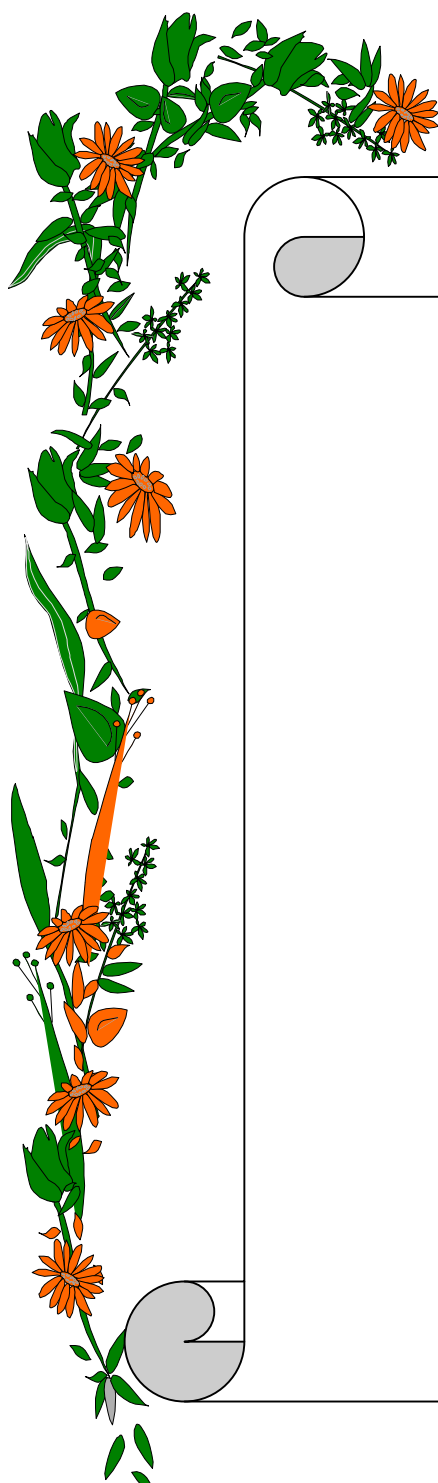
Rao *et al.* (2013) field observations were revealed that natural parasitisation of *G. nephantidis* on *O. arenosella* was 37.3 and

43.1 per cent in 2011 and 2012, respectively. Ansar *et al.* (2014) reported that the *Conogethes punctiferalis* Guenee parasitized by two larval parasitoids viz., *Apanteles taragamae* Vierick and *Glyptapanteles* sp. (Hymenoptera; Braconidae). It was the first report of naturally occurred larval parasitizing of *C. punctiferalis* in small cardamom. The abundance of larval parasitoids was maximum in the month of second fortnight of October. The per cent natural parasitization by larval parasitoids ranged from 3.36 to 43.31 per cent and pupal parasitoids ranged from 0.23 to 1.23 per cent.

Dhanapati *et al.* (2015) carried out survey work on lepidopteron pests infesting during 2013-2014 at various vegetable growing valley districts of Manipur. The study revealed that the occurrence of 15 species of parasitoids attacking 12 different host insects. Among them, braconids, ichneumonids, chalcids and bethylids were represented by 8, 3, 2 and 1 species, respectively. The percentage parasitism varied with parasitic species and it ranged from 10 to 60 per cent and most of the parasitoids showed their period of occurrence from February to September with peak activity in March and August. The reported parasitoids were *Cotesia glomerata* (Linnaeus) *Campoletis* sp., *Brachymeria lasus* (Walker), *Brachymeria bengalensis* (Cameron), *Cotesia plutellae* (Kurd), *Diadegma fenestralis* (Halmgrew), *Meteorus dichomeridis* (Wilkinson), *Carcelia* sp., *Glyptapanteles creatonoti* (Viereck), *Campoletis chlorideae* (Uchida), *Apanteles stantoni* (Ashmed) and *Apanteles* sp., *B. brevicornis* and *Goniozus* sp.. *Goniozus* sp. on *Sylepta derogata* (Fabricius).

Veeramuthu *et al.* (2015) found the two bethylids viz., *Holepyris* sp. and *Acrepyris* sp. and one braconid, *Coelinidea elegans* (Curtis). The months of July to December was found to be favourable to the hymenopteran insects. Vanitha (2015) documented three eulophid parasitoids, viz., *Chrysocharis* sp., *Closterocerus* sp. and *Aprostocetus* sp. for the first time as parasitoids on the larvae of

cashew leaf miner, *Acrocercops syngamma* (Meyrick) (Lepidoptera: Gracillariidae). Among the parasitoids, *Chrysocharis* sp. was dominant by recording 99.0 per cent abundance. The parasitism of leaf miner larvae was observed from September onwards, which reached its peak during November coinciding with the population of leaf miner larvae. *Chrysocharis* sp. was found to be a solitary parasitoid, completing its life cycle within the mine of leaf miner and emerging as an adult. The parasitization was noticed only on the third and fourth instar leaf miner larvae. The parasitism ranged from 37 to 58 per cent by *Chrysocharis* sp.



*MATERIALS
AND
METHODS*



III. MATERIALS AND METHODS

3.1 Description of study area

The study site, Bio-control Laboratory and PG Research Laboratory, Department of Entomology, N.M. College of Agriculture, Navsari Agricultural University, Navsari is situated at 13 km away in the East, from the great historical place, village Dandi on the Arabian seashore at 27° 57 N latitude, 72° 54 E longitude and at an altitude of 10 m above the Mean Sea Level (MSL). The climate is typically of tropical in nature exhibiting fairly hot summer, mild cold winter and more humid and warm monsoon. Monsoon generally commences from 2nd week of June and ends in the last week of September. The average annual rainfall during monsoon season is approximately 1606 mm in 54 rainy days. Winter season starts from November and lasts upto February. The summer starts from March and last upto May. Soils are classified as deep black soil with montmorillonite clay mineral.

The materials and methods used for investigation on various aspects of *Goniozus nephantidis* (Muesebeck) on factitious host, *Corcyra cephalonica* (Stainton) are presented hereunder.

3.2 Laboratory culture

3.2.1 Laboratory culture of *C. cephalonica*

The factitious host rice moth, *C. cephalonica* eggs were procured from Bio-control Laboratory, N. M. College of Agriculture, Navsari Agricultural University, Navsari. The culture was maintained and mass produced at PG Research Laboratory, Department of Entomology, N. M. College of Agriculture, Navsari Agricultural University, Navsari. The bold grains of sorghum var. *Nizar Goti* were milled in a domestic milling machine by making two to three pieces of each grain and heat sterilized in hot air oven at 100°C for 30 minutes to make free from any secondary infestation. Material was also been treated with streptomycin sulphate @ 0.2 g per kg, to prevent the bacterial infection. Crushed, raw groundnut @ 250 g was added to one

kilogram of sorghum and kept in pre sterilized circular galvanized trays (35 x 12 cm) as well as in glass jar (Plate-I to IV). Trays were arranged in a metal shelf. Ant well was also provided to avoid crawling of ants. Each tray was inoculated with 1000 eggs of *Corcyra* (0-1 hour old) and thoroughly mixed to have uniform distribution of eggs in food material. These trays were covered with white muslin cloth tied with a two-fold rubber band so as to avoid escape of either larvae. The trays were kept undisturbed for 15 days. After 15 days, the mature larvae were collected daily with manual collection in the morning hours in a small Petri dish from each tray. The collections of larvae were continued up to the formation of pupae. The laboratory culture of larvae was maintained for undertaking the further research aspects.

3.2.2 Rearing technique of parasitoid, *G. nephantidis*

The standard rearing method of *G. nephantidis* suggested by Venkatesan *et al.* (2008) with slight modification was adopted during the present investigation. The nucleus culture of *G. nephantidis* was procured from Main Coconut Research Station, Dr. Balasaheb Konkan Krishi Vidyapeeth., Bhatye (M.S). The parasitoid adults were obtained from the laboratory rearing stock culture and maintained on the mature and healthy larvae of *C. cephalonica* under laboratory condition (Plate-V). Male and female of *G. nephantidis* were released in to small plastic vials (7x2.5 cm) for mating under diffused light (Plate-VI)). Males and females were differentiated as female were larger in size with prominent ovipositor and males were smaller with blunted abdominal tip. The droplets of honey solution (50% diluted) on a wax coated paper stripes and water were provided as an adult food. After pre-oviposition period, the females were separated and kept in glass test tubes (13.5x1.5 cm) and covered with cotton plug to avoid escape of the adults. Later on, kept individually as there was contest behaviour among females, this involves aggressive postures, rapid chases and violent fights in which contestants attempt to bite



Plate- I: Galvanized tray with broken sorghum grains for rearing of *Corcyra* larvae under laboratory condition



Plate-II: Galvanized tray covered with white muslin cloth tied with a two-fold rubber band to avoid escape of larvae



Plate-III: Inside view of broken sorghum grains as a artificial diet for rearing of the *Corcyra* larvae



Plate-IV: Mass rearing of the *Corcyra* larvae in glass jar under laboratory condition



Plate-V: Plastic container for maintenance of stock culture of *G. nephantidis* under laboratory condition



Plate-VI: Plastic vials used for individual rearing of *G. nephantidis* under laboratory condition

and sting each other. The female was transferred every at 24 hours to a similar glass test tubes (13.5x1.5 cm) containing another fresh full-grown larva for egg deposition. The larva parasitized and containing eggs of *G. nephantidis* were removed regularly from the vials till the death of the female. Such larvae were kept in accordion type paper strips in plastic boxes for successful completion of lifespan. The developed cocoons were utilised in further investigations.

3.3 Biological aspects of ecto-larval parasitoid, *G. nephantidis*

The study on biology of *G. nephantidis* on *C. cephalonica* were carried out in the P.G. Research Laboratory, Department of Entomology, N.M. College of Agriculture, Navsari Agricultural University, Navsari during the year 2014-15. The biology of *G. nephantidis* on *C. cephalonica* was laid out under the laboratory condition at 25.51 ± 1.71 °C temperatures and 64.55 ± 2.97 per cent relative humidity. The immature stages of *G. nephantidis* on *C. cephalonica* were observed under dissecting stereo-trinocular microscope by using a very fine needle and moistened brush to determine the shape and duration of each stage. The length and breadth of various stages of *G. nephantidis* were calculated under stereo-trinocular microscope (Make: Olympus. SZ 61) fitted with Brand catcam-130 camera having software power Scopephoto (Version 3.1).

3.3.1 Egg period

Egg period of *G. nephantidis* on *C. cephalonica* was considered as period between date of egg laying to the date of egg hatching. The colour and shape of eggs were also observed.

3.3.2 Larval period

The total larval period of *G. nephantidis* on *C. cephalonica* was calculated from the date of egg hatching to the date of formation of pre- pupa (Pre-cocoon).

3.3.3 Pre-cocoon and Cocoon period

To know the pre-cocoon and cocoon period of *G. nephantidis* on *C. cephalonica*, observations were taken every day at morning during the larval development. To record the pre-cocoon period, the larva was observed from the time when it ceased feeding and became sluggish to the time when it turned in to cocoon. The duration between formations of cocoon to the emergence of adult was considered as cocoon period.

3.3.4 Adult period

Adults of *G. nephantidis* emerged from cocoons were observed to know their colour, shape and size of male and female and, it was differentiated on the basis of different morphological characteristics under stereo-trinocular microscope.

3.3.4.1 Pre-oviposition period, oviposition period and post oviposition period

In order to study the pre-oviposition, oviposition and post-oviposition period, the newly emerged adults of *G. nephantidis* were reared separately in plastic vial (7x2.5 cm). The pre-oviposition period was determined from the newly emerged adult pair. The adult food was provided with droplets of honey solution (50% diluted) on a wax coated paper stripes with help of moistened. The period between the emergence of adult female and commencing the egg laying was recorded as pre-oviposition period. The period between commencing the egg laying and ceasing of the egg laying by individual female was recorded as oviposition period. The period between ceasing of egg laying to death of female was considered as post oviposition period.

3.3.4.2 Adult longevity

Male and female adults of *G. nephantidis* emerged from cocoons were observed and maintained in a separate plastic vial (7x2.5 cm) to know the adult longevity.

3.3.4.3 Fecundity

To study the fecundity of *G. nephantidis* on *C. cephalonica*, eggs laid on healthy and mature larvae of *Corcyra* by individual female were counted daily in the morning. The total number of eggs laid by individual female during lifespan was considered as fecundity.

3.3.4.4 Sex ratio

In order to determine the sex ratio (Male: Female) of *G. nephantidis* under the laboratory condition, counted number of cocoons were kept in different plastic vials (7x2.5 cm). Male and female adults were identified on the basis of following morphological features. The abdomen of females was bulged at anterior portion and posterior end sharp with pointed ovipositor. The male abdomen was differs from females due to smaller in size with blunted posterior tip. Sex ratio was worked out from the laboratory culture.

3.3.5 Total life cycle

The duration of entire lifespan of *G. nephantidis* on *C. cephalonica* was considered as the period between date of egg laying to death of adults.

3.4 Parasitic potential of *G. nephantidis* on *C. Cephalonica*

The study on parasitic potential of *G. nephantidis* on *C. cephalonica* was carried out in P.G. Research Laboratory, Department of Entomology, N. M College of Agriculture, Navsari Agricultural University, Navsari during the year 2014-15. Observations pertaining to parasitic potential of *G. nephantidis* when reared on *C. cephalonica* were undertaken under laboratory condition at 25.51 ± 1.71 °C temperatures and 64.55 ± 2.97 per cent relative humidity.

The parasitic potential of *G. nephantidis* female was ascertained by exposing mature and healthy *Corcyra* larva to freshly emerged individual *G. nephantidis* pair from respective age group in a glass test tube (13.5x1.5 cm). Each mated female (After completion of pre-oviposition) was exposed to *Corcyra* larva only for 24 hours. On next day; a new larva of *Corcyra* in a same manner was exposed to



Plate-VII: Corcyra larvae provided to study the parasitic potential of *G. nephantidis* under laboratory condition



Plate-VIII: Parasitized larvae of Corcyra kept in Petri dish

each group of female. In this period, the females were fed on 50 per cent diluted honey solution in the form of small droplets on wax coated paper. After 24 hours, the respective larva was maintained in a separate plastic vial (7x2.5 cm) covered with cotton plug to avoid escape of the adults (Plate- VII to VIII). The parasitic behaviour and time taken to initiate oviposition was also measured. The larvae parasitized and containing eggs of *G. nephantidis* were removed regularly from the vials till the death of the female. Such larvae were kept in accordion paper strips in separate plastic bottle. The plastic bottle was covered with muslin cloth. Blackened larva was also considered to know the parasitic potential of female of *G. nephantidis*. The results were expressed as the number parasitized larvae of *Corcyra* by *G. nephantidis*. Moreover, the eggs laid by individual female per larva were considered as clutch size of single female, thus parasitic potential of an adult female was worked out.

3.5 Relative toxicity of various insecticides against *G. nephantidis*

To determine the relative toxicity of different insecticides against adults of *G. nephantidis* obtained from laboratory culture and they were used in susceptibility test to different insecticides at Bio-control Laboratory, Department of Entomology, N.M. College of Agriculture, Navsari Agricultural University, Navsari.

3.5.1 Details of experiment

Location	:	Biological control Laboratory, Department of Entomology, N.M.C.A., N.A.U., Navsari
Year of experiment	:	2015-16
Experimental design	:	Completely Randomized Design (CRD)
No. of treatments	:	10 (Ten)
No. of repetitions	:	3 (Three)
Treatment details	:	As per given Table-02

3.5.2 Details of insecticidal treatment are given in Table-02

3.5.3 Method of insecticidal application

The insecticides were evaluated for their safety to the parasitoid. Contact toxicity of insecticides was determined as per methodology suggested by Jalali and Singh (1993). A transparent plastic vials (7x2.5 cm) with a plastic lid converted in to a pesticide-testing unit by making a small holes in middle of lid to avoid fumigant effect of insecticides and to provide aeration. The prepared solution of insecticide was sprayed on all inner sides of vials and lid with an atomizer and both were then air-dried thoroughly. In control treatment, only water spray was done. Ten newly emerged adults of *G. nephantidis* were introduced per treatment per repetition individually in to plastic vials and exposed to treated surface freely. The honey solution 50 per cent diluted was provided in the form of fine streak on wax coated paper stripes.

3.5.4 Method of observations

Observations on the mortality of *G. nephantidis* adults were recorded at 12, 24, 48 and 72 hours after constant exposure. The data obtained on per cent adult mortality of *G. nephantidis* converted into arc sine transformation values and then subjected to statistical analysis. The magnitude of the response of toxicant exposure on the parasitoid, *G. nephantidis* was subjected to classified as per International Organization for Biological Control (IOBC) toxicity rating (Sterk *et al.*, 1999). For laboratory trials, IOBC employs a following scale to categories the tested insecticides. Thus, the same scale was also employed in present investigation to differentiate the evaluated insecticides into various groups of toxicity.

Score	IOBC toxicity rating for natural enemies	
	Mortality (%)	Category
1	<25% mortality	Harmless
2	25-50% mortality	Slightly harmful
3	51-75% mortality	Moderately harmful
4	>75% mortality	Harmful

3.6 Natural occurrence of larval parasitoids on black headed caterpillar, *Opisina arenosella* Walker under Navsari condition.

3.6.1 Details of experiment

Location	:	Coconut plantation (AICRP on Palms) Regional Horticultural Research Station, NAU., Navsari
Year of experiment	:	2015
Crop and Variety	:	Coconut var. Hybrid D x T
Area	:	01 ha
Spacing	:	7.5 x 7.5 m
Sample size	:	10 % area of the selected palm garden

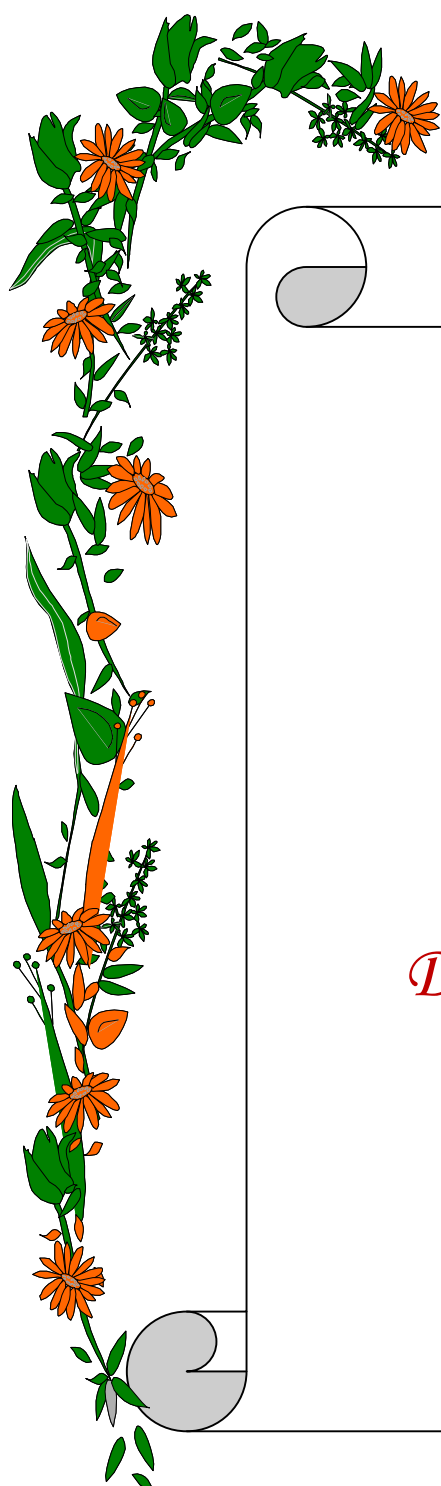
3.6.2 Method of observations

To record the occurrence of larval parasitoids of coconut black headed caterpillar under Navsari, fixed plot surveys were carried out in coconut plantation garden at RHRS, Navsari from January 2015 to December 2015. The methodology suggested by Sujatha and Chalam (2009) was employed with slight modification during the present investigation. For this purpose, one coconut garden having 1.0 ha area was selected; among them 10 per cent area was selected for sample size. The palms were selected randomly at each observation and it was recorded at fortnightly interval from lower 5 leaflets/selected palm. From each selected palm, collect all the larval stages of black headed caterpillar, to know the natural parasitism.

The collected larval stages of black headed caterpillars were brought to P.G. Research Laboratory, Department of Entomology, N. M. College of Agriculture, Navsari Agricultural University, Navsari for the emergence of adults of parasitoid. These collected parasitoids were kept individually in a separate plastic glass vials (7x2.5 cm) to avoid the assimilation of species. Adult specimens of parasitoids were also collected directly by aspirator and differentiated on the basis of

their morphological characters. Thus, the number of different species present on each selected palm was worked out. These collected stages were kept individually in plastic vials (7x2.5 cm) for the emergence of parasitoid under constant supervision. The number of parasitoids emerged from each larval stage of black headed caterpillar were recorded daily. Thus, per cent parasitization of black headed caterpillar was worked out. The collected specimens of parasitoids were kept in specimen glass tube (5.5x1.5 cm) and sent to ICAR-National Bureau of Agricultural Insect Resources (NBAIR) (Formerly, NBAII and PDBC), Bengaluru (Karnataka) for identification and confirmation. The specimens were identified by Hymenopteran Parasitoid Expert as *Goniozus nephantidis* (Muesebeck) (Bethyridae: Hymenoptera) and *Habrobracon hebetor* Say (Braconidae: Hymenoptera) during the present investigation.

Table-02: Details of insecticidal treatment against adults of <i>G. nephantidis</i> under laboratory condition in present investigation					
Treat. No.	Name of insecticides	Conc. (%)	Dose (per litre)	Trade name and formulations	Source
T ₁	Indoxacarb 15.8 % EC	0.01%	0.63ml	Avaunt 15.8 % EC	DuPont India Private Limited. 81,82,83, 8th floor, 2 North Avenue, Maker Maxity, Bandra Kurla Complex, Bandra (East) Mumbai-400051, India.
T ₂	Emamectin benzoate 5% SG	0.0025%	0.5g	EM-1 5% SG	Danuka Agritech Limited, DI/A B Agritech industril estate, Village, Veane. Ahamadbad.
T ₃	Chlorpyriphos 20 % EC	0.05%	2.5ml	Chloryguard 20 %EC	Gharda Chemical Limited, 48 Hills Road , Bandra (W), Mumbai-400050, India,
T ₄	Quinalphos 25 % EC	0.05%	2.0ml	Ekalux 25 % EC	Sandos India Ltd. A.B Road, Worli. Mumbai 400018
T ₅	Flubendiamide 39.35 % SC	0.0096%	0.25ml	Fame 480 % SC	Bayer Crop science Limited. Plot No. 306/3, II Phase GIDC, Vapi – 396195 Gujarat, India.
T ₆	Spinosad 45 % SC	0.002%	0.044ml	Taffin 45 % SC	Dow Agro-science India Pvt. Ltd. Factory: 228.GIDC, Panoll, Dist, Bharuch, Gujarat, India.
T ₇	Profenofos 50 % EC	0.075%	1. 5 ml	Prahar 50 % EC	Biostadt India Limited 602-A, Poonam chamber, Dr. A.B Road, Mumbai-40018, Maharastra, India.
T ₈	Dichlorvos 76 % EC	0.05%	0.65ml	Dodak 76 % EC	Herbal Industries Ltd., 101. Khanchanaganga. Factory line, Borivili (W), 1503, GIDC, Phage 3, Vapi Dist Valsad, Gujarat, India.
T ₉	Triazophos 40 % EC	0.05%	1.25ml	Trizocel 40 % EC	Excel Crop Care Limited, Registered office 184-87, SV. Road, Jogeshwari (West), Mumbai-400102, India.
T ₁₀	Control (Water spray)	-	-	-	-



*RESULTS
AND
DISCUSSION*



IV. RESULTS AND DISCUSSION

4.1 Biology of *Goniozus nephantidis* (Muesebeck) on *Corcyra cephalonica* (Stainton)

The present investigation on “Biology and parasitic potential of ecto-larval parasitoid, *G. nephantidis* (Bethyridae: Hymenoptera) under South Gujarat conditions” was carried out in the P.G. Research Laboratory, Department of Entomology, N.M. College of Agriculture, Navsari Agricultural University, Navsari at 25.51 ± 1.71 °C temperatures and 64.55 ± 2.97 per cent relative humidity during 2014-15. The results obtained during the present studies are presented in Table-02 to Table-14 (Graphically depicted in Fig.-1 to 5) and discussed hereunder [Plate-IX to XXIII].

4.1.1 Egg

4.1.1.1 Site and pattern of egg laying

During the present study on biology of *G. nephantidis* (Plate-IX to X), it was observed that the maximum number eggs of *G. nephantidis* were laid on the on dorso-lateral side of 5th to 6th abdominal segments of *C. cephalonica* larvae and there were not any egg on the first segment of abdomen, thorax and the last segment of abdomen. The egg was loosely attached to the host's integument and deposited parallel to the longitudinal axis of the body. The maximum eggs were deposited with definite site preference by the female parasite. The orientation of the egg was precise, though it was not as per the direction of the female's ovipositional posture. The most of eggs were placed on dorso-lateral side of the host larvae. The present findings are more or less agreed with Gordh (1976) who reported *G. gallicola* prefers to laid eggs on the host dorsum, especially on 6 to 9 segments; *G. nephantidis* lays eggs on lateral side of the host body and eggs were laid on all the segments except the first thoracic and the last four abdominal segments (Remadevi





Male adult



Female Adult

Plate-X: Male and female adults of *G. nephantidis* during present investigation

et al., 1978; 1995); majority of eggs were laid close to the intersegmental folds on the lateral aspect while some on the dorsal aspect and the fewest on the ventral aspects by *G. natalensis* (Conlong *et al.*, 1988); while eggs of *G. swirskiana* were laid on all the segments except the first thoracic and the last four abdominal segments of *Batrachedra amydraula* Meyrick and there were not any egg on thorax (Elahe *et al.*, 2012).

4.1.1.2 Colour, shape and size

It can be seen from present studies of *G. nephantidis* that the freshly laid eggs were creamy white in colour and become translucent later. The deposited eggs were spindle shaped slightly curved, hyaline colourless and loosely attached to the surface of the host body (Plate-IX to X). The data on measurement of length and breadth of the eggs are presented in Table-3 revealed that the length of eggs varied from 0.37 to 0.59 mm with an average of 0.48 ± 0.06 mm, whereas the breadth ranged from 0.18 to 0.29 mm with an average of 0.23 ± 0.03 mm. In past, similar report on colour, shape and size was noted by Gordh (1976) who reported that the eggs of *G. gallicola* measured approximately about 0.8 mm in length and 0.2 mm in diameter; 0.6 mm in length and 0.2 mm in breadth of eggs of *G. natalensis* (Conlong *et al.*, 1988); eggs of *G. nephantidis* were opaque, milky white in colour, elongated, almost cylindrical and measured about 0.5 mm in length and 0.1 mm in breadth (Stinne and Hardy, 2000); whereas length of *G. nephantidis* was 0.50 ± 0.01 mm in length and 0.15 ± 0.01 mm in breadth (Sreekanth and Muralimohan, 2013b). Seetharama *et al.* (2007) who measured that the eggs length of *Apenesia sahyadrics* (Azevedo and Waichert) ranged from 0.29 to 0.36 mm and breadth ranged from 0.29 to 0.36 mm while length and breadth of eggs were 0.57 mm and 0.15 mm, respectively for *B. hebetor* (Shah *et al.*, 2014). The results of previous workers are slightly differed with the present findings. The variation in size of eggs might be due to change in artificial diet as honey to the adults parasitoids and

Table-03: Morphometrics of various stages of <i>G. nephantidis</i> on <i>C. cephalonica</i> under laboratory conditions										
Sr. No.	Eggs		Larva		Cocoon		Male Adult		Female Adult	
	Length (mm)	Breadth (mm)	Length (mm)	Breadth (mm)	Length (mm)	Breadth (mm)	Length (mm)	Breadth (mm)	Length (mm)	Breadth (mm)
1	0.47	0.19	1.94	0.47	3.31	1.12	1.17	0.45	1.64	0.81
2	0.49	0.21	2.16	0.40	4.32	2.21	1.33	0.36	1.63	0.73
3	0.51	0.24	2.31	0.35	3.31	1.81	1.41	0.37	1.90	0.49
4	0.57	0.27	2.23	0.33	4.32	2.11	1.16	0.66	1.66	0.43
5	0.51	0.26	1.92	0.32	5.13	2.21	1.28	0.72	2.33	1.23
6	0.59	0.21	2.01	0.33	4.11	1.92	1.33	0.40	2.11	1.01
7	0.49	0.18	2.19	0.29	3.05	1.72	1.15	0.59	1.91	0.90
8	0.37	0.26	2.01	0.37	4.21	2.16	1.17	0.78	2.90	0.99
9	0.38	0.25	2.08	0.44	4.10	1.13	1.24	0.52	1.95	0.89
10	0.37	0.23	2.18	0.35	3.21	1.07	1.31	0.42	1.22	0.55
11	0.38	0.24	2.10	0.35	5.11	2.08	1.11	0.50	1.54	0.70
12	0.39	0.20	2.14	0.33	5.09	1.08	1.51	0.38	1.50	1.20
13	0.50	0.19	2.21	0.51	4.25	1.26	1.24	0.48	2.11	1.33
14	0.52	0.21	2.25	0.41	3.75	2.27	1.17	0.52	2.08	0.99
15	0.47	0.24	2.16	0.39	3.48	2.83	1.20	0.40	2.90	0.35
16	0.48	0.26	2.20	0.53	4.12	2.91	1.14	0.33	1.50	0.66
17	0.45	0.24	2.16	0.48	5.01	2.21	1.19	0.81	1.91	1.04
18	0.47	0.27	2.18	0.51	4.16	2.36	1.65	0.75	1.23	1.10
19	0.49	0.29	2.21	0.52	4.05	1.36	1.16	0.41	1.52	0.78
20	0.51	0.23	2.31	0.56	3.18	1.93	1.14	0.51	1.46	0.52
21	0.50	0.19	2.14	0.54	3.40	1.56	1.48	0.61	2.30	0.99
22	0.57	0.20	2.24	0.45	4.90	1.84	1.18	0.41	2.10	1.21
23	0.53	0.21	2.28	0.35	3.83	2.54	1.16	0.56	1.91	0.92
24	0.55	0.24	2.31	0.41	3.81	2.10	1.30	0.45	1.92	1.10
25	0.51	0.23	2.15	0.40	3.71	2.91	1.12	0.38	1.93	1.25
26	0.49	0.24	2.13	0.49	4.01	2.01	1.34	0.54	1.87	0.98
27	0.47	0.26	2.11	0.41	3.15	1.98	1.31	0.61	1.45	1.02
28	0.50	0.28	2.20	0.51	3.49	2.54	1.33	0.51	1.32	1.05
29	0.52	0.24	2.21	0.49	3.87	2.15	1.06	0.39	1.64	1.48
30	0.47	0.25	2.41	0.50	4.09	2.08	1.17	0.41	1.33	1.55
Min.	0.37	0.18	1.92	0.29	3.05	1.07	1.06	0.33	1.22	0.35
Max.	0.59	0.29	2.41	0.56	5.13	2.91	1.65	0.81	2.90	1.55
Av.±S.D.	0.48 ±0.06	0.23±0.03	2.17±0.11	0.43±0.08	3.98±0.61	1.98±0.52	1.25±0.13	0.51±0.13	1.83±0.42	0.94±0.30

Table- 04: Biological attributes of <i>G. nephantidis</i> under laboratory conditions				
Sr. No.	Egg period (Days)	Larval period (Days)	Pre-cocoon period (Days)	Cocoon period (Days)
1	2	5	1	6
2	1	3	2	5
3	2	4	1	7
4	2	4	2	6
5	3	3	1	5
6	2	4	2	4
7	2	3	1	6
8	2	3	2	6
9	1	4	2	5
10	2	5	1	7
11	3	3	2	6
12	2	5	1	5
13	1	4	1	6
14	2	5	2	4
15	3	4	1	7
16	2	5	2	6
17	1	4	2	5
18	3	3	1	4
19	2	5	2	6
20	1	4	2	7
21	3	3	1	6
22	2	5	2	5
23	2	5	1	4
24	3	4	1	5
25	2	3	2	6
26	3	5	2	5
27	2	4	1	4
28	3	3	1	6
29	1	5	2	5
30	3	4	2	7
Min.	1	3	1	4
Max.	3	5	2	7
Av.± S.D.	2.10 ± 0.71	4.03 ± 0.81	1.53 ± 0.51	5.53 ± 1.00

sorghum to the larvae of host insect during study period and fluctuation in prevailing weather parameters.

4.1.1.3 Incubation period

The data recorded on incubation period of *G. nephantidis* presented in Table-4 that the incubation period was ranged from 1.0 to 3.0 days with an average of 2.10 ± 0.71 days. The exact time of exclusion was exceedingly difficult to determine, since virtually no external change occurs at the time of moulting. Once the egg hatches, the position of the larva remains fixed. In past, almost identical durations were noticed by Conlong *et al.* (1988) who reported that the incubation period of *G. natalensis* was 3 days; 3.1 ± 0.0 days for *G. thailandensis* (Witethom and Gordh, 1994); incubation period was shortest on *Pectinophora gossypiella* (Saunders) (1.64 ± 0.04 days) and prolonged (1.80 ± 0.04 days) on *E. Ephestia kuehniella* (Zeller) for *G. legneri* (Shoeb *et al.*, 2005). All above findings are in accordance with the present investigation on incubation period of *G. nephantidis*.

In past, present findings are more or less similar with some other larval parasitoids. Seetharama *et al.* (2007) who reported that the incubation period of *A. sahyadrics* ranged from 2 to 5 days; 22.00 to 25.00 hrs and 23.30 to 26.00 hrs for *Bracon hebetor* Say on *C. cephalonica* and *Opisina arenosella* Walker, respectively (Landge *et al.*, 2009), while the shorter and prolonged egg period was 0.91 and 1.68 days on *C. cephalonica* and *Spodoptera litura* Fabrius respectively for *B. hebetor* (Dabhi *et al.*, 2013); 1.12 days and 1.18 days for *Bracon brevicornis* (Wesmael) on 4th and 5th instar larva of *Plodia interpunctella* (Hubner) (Malesios and Prophetou, 2014); The present findings are also in line to report of Reda *et al.* (2014) who found that the incubation period *B. brevicornis* was prolonged in case *E. kuehniella* (39.87 ± 0.95) hours and shortest in *G. Galleria mellonella* (Linnaeus) (31.53 ± 1.22 hours). The present investigation agreed with Farag *et al.* (2015) who reported that the incubation period of *B. hebetor* eggs was shortest (1.3 ± 0.053 days) in *C. cephalonica*, while it was prolonged in

E. kuehniella (1.55 ± 0.09 days). The slight variation in incubation period might be due to weather conditions existing in a particular locality and methodology used for the study.

4.1.1.4 Hatching (%)

Present investigation on the per cent of egg hatching (Table-5) that the egg hatching of *G. nephantidis* on *C. cephalonica* varied from 75.71 to 95.24 per cent with an average of 87.03 ± 5.86 per cent. The present findings cannot be compared as there is no information available pertaining to this aspect.

4.1.2 Larva

4.1.2.1 Colour, shape and size of larva

The colour, shape and size of larva of *G. nephantidis* revealed that the first instar was apodous, white, devoid of any sign of external segmentation and distinguished from the egg only by waves of internal content of gut contraction and the movement of haemolymph within the parasite's body (Plate-IX to X). The later instar larvae were whitish yellow and having clear larval body segmentation. The full grown larvae with tapering end and bulge of middle portion of larval body. Moreover, the length of *G. nephantidis* larvae varied from 1.92 to 2.41 mm with an average of 2.17 ± 0.11 mm. The breadth of larvae varied from 0.29 to 0.56 mm with average of 0.43 ± 0.08 mm (Table-3). The present studies are in accordance with past worker i.e. Shoeb *et al* (2005) who indicated that the first instar larvae of *G. legneri* was apodous and hymenopterous form. The body of second instar larva was creamy in colour and movements of internal organs were seen on external observations, while the body of the third larval instar was yellowish.

In past, present findings on colour, shape and size of larva are more or less similar in some other larval parasitoids and data revealed that Seetharama *et al.* (2007) who reported that the larva of *A. sahyadrics* measured a length of 6.36 ± 0.22 mm (range 3.28 to 8.58 mm) and width 1.23 ± 0.02 mm (range 1.00 to 1.43 mm). The result are also agreed with findings of Shah *et al.* (2014) who affirmed that the

Table- 05: Hatching (%) of <i>G. nephandidis</i> under laboratory conditions				
Sr. No.	Period of study	No. of eggs observed	No. of eggs hatched	Hatching percentage
1	25/03/2015 to 28/03/2015	55	49	89.09
2	26/03/2015 to 27/03/2015	44	41	93.18
3	27/03/2015 to 30/03/2015	51	43	84.31
4	28/03/2015 to 30/03/2015	53	44	83.02
5	29/03/2015 to 31/03/2015	62	57	91.94
6	30/03/2015 to 1/04/2015	41	38	92.68
7	31/03/2015 to 2/04/2015	65	55	84.62
8	1/04/2015 to 3/04/2015	57	49	85.96
9	2/04/2015 to 3/04/2015	51	41	80.39
10	1/04/2015 to 3/04/2015	40	35	87.50
11	2/04/2015 to 5/04/2015	46	37	80.43
12	3/04/2015 to 5/04/2015	42	40	95.24
13	4/04/2015 to 6/04/2015	51	42	82.35
14	5/04/2015 to 7/04/2015	65	61	93.85
15	6/04/2015 to 7/04/2015	70	53	75.71
16	7/04/2015 to 9/04/2015	66	62	93.94
17	8/04/2015 to 9/04/2015	58	46	79.31
18	9/04/2015 to 11/04/2015	46	43	93.48
19	10/04/2015 to 12/04/2015	42	35	83.33
20	11/04/2015 to 12/04/2015	61	55	90.16
Min.				75.71
Max.				95.24
Av. ± S. D.				87.03 ± 5.86

minimum and maximum larval length of *B. hebetor* were 0.40 and 3.67 mm, respectively with a mean of 1.69 mm. The mean breadth of larva was 0.66 ± 0.07 mm with a range of 0.13 and 1.33 mm.

4.1.2.2 Larval period

The perusal of data presented in Table-4 revealed that the larval period of *G. nephantidis* on *C. cephalonica* varied from 3.0 to 5.0 days with an average of 4.03 ± 0.81 days. Present studies on larval period are in accordance with Kapadia and Mittal (1993) who found that the larval period of *G. nephantidis* was shortest during June-July (4.0 days) compared with other months (5.15–5.83 days) on *C. cephalonica*; 4.1 days for *G. thailandensis* (Witethom and Gordh, 1994); 2.20 ± 0.11 and 2.99 ± 0.12 days larval period for *G. legneri* on *E. kuehnniella* and *P. gossypiella*, respectively (Shoeb *et al.*, 2005); shortest and prolonged period was 22.16 ± 1.59 and 41.22 ± 5.11 for male *G. nephantidis* while 24.95 ± 2.25 and 46.07 ± 4.52 days for female *G. nephantidis* (Sreekanth and Muralimohan, 2013a). Seetharama *et al.* (2007) who reported that the total larval period of *A. sahyadrics* was 7.56 ± 0.12 days and ranged from 5.83 to 8.00 days; 60.00 to 69.60 hours and 60.00 to 79.20 hours for *B. hebetor* on *C. cephalonica* and *O. arenosella*, respectively (Landgeet *al*, 2009). Moreover, period was prolonged as 3.84 days on *Helicoverpa armigera* (Hubner) and shortest as 2.66 days on *C. cephalonica* for *B. hebetor* (Dabhi *et al.*, 2013); 2.03 ± 0.06 and 1.68 ± 0.03 days for *B. brevicornis* on 4th and 5th instar larvae of Indian meal moth (Malesios and Prophetou, 2014); 3.17 ± 0.11 days and ranged from 2.4 to 4 days for *B. brevicornis* (Shah *et al*, 2014). The slight variation in larval period might be due to change in test insect, rearing media used, prevailing weather conditions existing in a particular locality and methodology used for the study.

4.1.3 Cocoon

4.1.3.1 Colour, shape and size of cocoon

The data presented pertaining to biological attributes of cocoon of *G. nephantidis* revealed that the final instar larva ceased feeding and

then search suitable place, where it remained stationary. This formed the beginning of cocoon formation stage. The caudal region was firmly attached to the substrate; the body was shrunken during the formation of pre-pupa and the fully-grown larvae were started producing silken threads that were used for making of cocoon. The cocoon of *G. nephantidis* was made loosely woven by silken threads and white in colour with oblong in shape and become tough attached with substrate. The length of *G. nephantidis* cocoon varied from 3.05 to 5.13 mm with an average of 3.98 ± 0.61 mm, while breadth ranged from 1.07 to 2.91 mm with an average of 1.98 ± 0.52 mm (Table-3). The present findings on morphological description of cocoon was akin to findings of Gordh (1976) who reported that the pre-pupa of *G. gallicola* was superficially resemble to the feeding larva except the cuticle was opaque and urete cells were distinctly white. The cocoon of *G. gallicola* was loosely woven white and measured about 5 mm in length and 1.5 mm in diameter.

Present findings on cocoon were correlated with other larval parasitoid i.e Seetharama *et al.* (2007) who noted that the pupae of male *A. sahyadrics* was 6.02 ± 0.16 mm in length and 1.25 ± 0.03 mm in width. In case of female, it was 6.34 ± 0.18 mm in length and 1.3 ± 0.32 mm in width; the mean length of cocoon was 3.72 mm with a range of 3.3 to 4.1 mm, while the minimum and maximum breadth of cocoon was 1.0 and 2.1 mm, respectively with a mean of 1.58 ± 0.079 mm for *B. hebetor* (Shah *et al.*, 2014). Above findings are more or less similar with present studies on *G. nephantidis* under laboratory condition.

4.1.3.2 Pre- cocoon period

Looking to the data presented in Table-4 indicated that the duration of pre-cocoon varied from 1.0 to 2.0 days with an average of 1.53 ± 0.51 days. Present findings are more or less corroborated with Gordh (1976) who reported that the duration of pre-pupal stage was 3.0 to 5.0 days; shortest as 0.73 ± 0.04 days on *E. kuehniell* and prolonged

as 0.84 ± 0.05 days on *Phthorimaea operculella* (Zeller) for *G. legneri* (Shoeb *et al.*, 2005).

In past, Landge *et al.* (2009) affirmed that the pre-pupal period of *B. hebetor* ranged from 0.40 to 0.50 days and 0.85 to 1.00 days on *C. cephalonica* and *O. arenosella*, respectively. Moreover, it was maximum (1.22 days) on *S. litura* and minimum (0.84 days) on *C. cephalonica* for *B. hebetor* (Dabhi *et al.*, 2013); 1.47 ± 0.08 and 1.29 ± 0.04 days on 4th and 5th larval instar of Indian meal moth for *B. brevicornis* (Malesios and Prophetou, 2014).

4.1.3.3 Cocoon period

During the course of investigation on cocoon period of *G. nephantidis* under laboratory condition data revealed that the cocoon period varied from 4.0 to 7.0 days with an average of 5.53 ± 1.00 days (Table-4). The present finding is in conformity with the reports of Kapadia and Mittal (1993) who reported that the pupal period was 6.56 and 10 days in January to February and May to June, respectively; 13.5 ± 0.1 days for *G. thailandensis* (Witethom and Gordh, 1994); shortest 8.50 ± 0.49 days on *E. kuehniell* and prolonged 9.33 ± 0.47 days on *P. operculella* for *G. legneri*.

Landge *et al.* (2009) who noted that the pupal period of *B. hebetor* ranged from 4.0 to 5.0 days and 5.0 to 6.0 days on *C. cephalonica* and *O. arenosella*, respectively; shorter (3.71 days) on *C. cephalonica* and prolonged on *S. litura* (5.92 days) for *B. hebetor* (Dabhi *et al.*, 2013); minimum (6.07 ± 0.23 days) on *G. mellonella* and maximum (7.6 ± 0.13 days) on *P. gossypiella* for *B. brevicornis* (Reda *et al.*, 2014); 6.82 ± 0.09 and 7.76 ± 0.04 days on 4th and 5th larval instar of Indian meal moth for *B. brevicornis* (Malesios and Prophetou, 2014). The slight deviation in cocoon period might be due to change in test insect, rearing media used, prevailing weather conditions existing in a particular locality and methodology used in their investigation.

4.1.4 Adult

4.1.4.1 Colour, shape and size of adult

The newly emerged adults were black in colour with transparent membranous wings, head of the adults were also black in colour and blunted triangular in shape with sharp brown to black colour mandibles. The antennae were filliform with 13 segmented; yellowish-brown in colour and attached to head by scape. The thorax was black in colour with 3 segmented and bears two pairs of membraneous wings on 2nd and 3rd segments, three pairs of yellowish-brown legs present all thoracic segments. The abdomen of females was bulged at anterior portion and sharp at posterior end with pointed ovipositor. The male abdomen differs from females due to short blunted posterior tip (Plate-X). The length of the male was shorter as compared to females.

The data on measurements of body length and breadth of male and female revealed that, the body length of male varied from 1.06 to 1.65 mm with an average of 1.25 ± 0.13 mm and breadth varied from 0.33 to 0.81 mm with an average of 0.51 ± 0.13 mm, while the body length of female ranged from 1.22 to 2.90 mm with an average of 1.83 ± 0.42 mm and breadth ranged from 0.35 to 1.55 with an average of 0.94 ± 0.30 mm (Table-3). A more or less similar description on measurements of *G. nephantidis* had narrated by Gordh (1976) who found that the body of *G. gallicola* was translucent within cocoon and at time of adult emergence; tergites and sternites become black in colour and finally adult appeared as black in colour. Moreover, *G. thailandensis* was predominantly black with antenna dusky yellow, apical segment very faintly light. Coxae and femur dark reddish brown; tibiae and tarsomeres had yellowish tan, tarsal claws had black and female body length ranged from 2.9 to 5.0 mm (Gordh and Witethom, 1993); when progeny produced by larger females (0.52 ± 0.02 mm in male and 0.86 ± 0.05 mm in female) and progeny produced by smaller females (0.48 ± 0.05 mm male and 0.78 ± 0.07 mm female). Average head width of small and large female was 0.75 ± 0.05 mm and 0.90 ± 0.02 mm, respectively

(Sreekanth and Muralimohan, 2013b). The present investigation on colour and size of adult *G. nephantidis* are tally with Shah *et al.* (2014) who reported that the length of *B. hebetor* male and female adult varied from 2.75 to 3.25 mm and 3.0 to 4.0 mm with a mean of 3.02 and 3.43 mm, respectively. The mean breadth of male and female were 5.46 and 5.63 mm, respectively. Later on, the length of the male of *A. sahyadrics* ranged from 5.0 to 8.58 mm and width ranged from 0.86 to 1.72 mm. The females were measured about 6.53 ± 0.18 mm in length (Seetharama *et al.*, 2007). The slight variation in morphometrical characters might be due to change in test insect, rearing media used, prevailing weather conditions existing in a particular locality and methodology adopted for their investigation.

4.1.4.2 Pre-oviposition period

Looking to the data (Table-6) it can be seen that the pre-oviposition period varied from 3.0 to 6.0 days with an average of 4.70 ± 0.95 days. Present studies results are more or less concur with Conlong *et al.* (1988) who reported that the pre-oviposition period was 2 to 3 days for *G. natalensis*; 4.4 ± 0.4 days for *G. thailandensis* (Witethom and Gordh, 1994); 2.60 to 1.02 days on *E. kuehniella* and 3.13 ± 0.88 days on *P. gossypiella* larva for *G. nephantidis* (Shoeb *et al.*, 2005); 4.20 ± 1.00 days on *O. arenosella* and pre-oviposition period of large sized female was 4.75 ± 1.21 days as compared to small sized females (6.15 ± 1.53 days) for *G. nephantidis* (Sreekanth and Muralimohan, 2013a and 2013b); Present studies data on pre-oviposition period of *G. nephantidis* are akin to past workers viz., Seetharama *et al.* (2007) who reported that the pre-oviposition period of *A. sahyadrics* was 12.48 ± 0.63 days; 11 to 19 hours and 15 to 20 hours on *C. cephalonica* and *O. arenosella*, respectively for *B. hebetor* (Landge *et al.*, 2009); 8.9 ± 5.0 days on *E. kuehniella* for *f* (Redolfi and Campos, 2010); 0.64 to 0.86 day for *B. hebetor* (Dabhi *et al.*, 2013); prolonged as 2.0 ± 0.21 days on *C. cephalonica* and shortest as 1.0 ± 0.29 days on *P. gossypiella* for *B. hebetor* (Reda *et al.*, 2014).

Table-06: Adult longevity and fecundity of <i>G. nephandidis</i> under laboratory conditions						
Sr. No.	Pre-oviposition period (Days)	Oviposition period (Days)	Post-oviposition period (Days)	Adult longevity (Days)		Fecundity (Nos.)
				Female	Male	
1	4	16	3	23	13	82
2	5	21	2	29	11	77
3	4	18	4	27	12	83
4	6	19	3	28	15	57
5	3	21	3	28	15	80
6	6	22	4	32	12	51
7	5	15	2	22	13	79
8	3	14	3	21	11	68
9	6	16	3	25	16	76
10	4	18	2	24	9	65
11	6	13	3	22	17	81
12	5	25	3	33	15	87
13	6	24	2	32	11	56
14	4	20	3	27	15	47
15	5	13	4	22	16	88
16	4	18	3	25	15	69
17	6	16	2	24	9	65
18	4	21	3	28	14	57
19	5	24	3	32	10	68
20	4	15	5	24	19	51
21	6	19	3	28	15	94
22	5	16	2	23	19	53
23	4	19	3	28	9	88
24	4	23	2	29	19	85
25	5	21	2	29	17	62
26	5	16	3	24	13	81
27	5	20	2	27	11	78
28	4	17	2	23	17	76
29	5	21	3	29	15	89
30	3	18	2	24	10	84
Min.	3	13	2	21	9	47
Max.	6	25	5	33	19	94
Av. ± S.D.	4.70 ± 0.95	18.63 ± 3.27	2.80 ± 0.76	26.40 ± 3.39	13.77 ± 3.05	72.57 ± 13.41

4.1.4.3 Oviposition period

The oviposition period of *G. nephantidis* varied from 13.0 to 25.0 days with an average of 18.63 ± 3.27 days (Table-6). Earlier, Shoeb *et al.* (2005) who reported that the oviposition period of *G. nephantidis* was prolonged as 16.13 ± 0.88 days on *E. kuehniella* and shorter as 14.93 ± 2.69 days on *P. gossypiella*; oviposition period of large sized females had 29.55 ± 5.24 days and small sized females had 22.80 ± 3.76 days for *G. nephantidis* (Sreekanth and Muralimohan, 2013b).

The present findings on oviposition period of *G. nephantidis* are more or less in agreement with findings of Seetharama *et al.* (2007) who indicated that the ovipositional period of *A. sahyadrics* was 2.74 ± 0.15 days; 10 to 57 and 18 to 37 days on *C. cephalonica* and *O. arenosella*, respectively for *B. hebetor* (Landge *et al.*, 2009); prolonged 28.41 days on *C. cephalonica* and shortest 15.76 days on *S. litura* for *B. hebetor* (Dabhi *et al.*, 2013); maximum as 16.8 ± 0.68 days on *S. cretica* and shortest as 10.4 ± 0.97 days on *C. cephalonica* for *B. hebetor* (Reda *et al.*, 2014).

4.1.4.4 Post oviposition period

Looking to the data (Table-6), it can be seen that the post oviposition period varied from 2.0 to 5.0 days with an average of 2.80 ± 0.76 days. The present findings are tally with Shoeb *et al.* (2005) who suggested that the post- oviposition period of *G. nephantidis* was shorter on *E.kuehniella* (1.93 ± 1.23 days) and prolonged on *P. gossypiella* (2.20 ± 1.38 days); while it was prolonged on large sized females was 12.15 ± 3.41 days as against 10.45 ± 2.42 days on small sized females for *G. nephantidis* (Sreekanth and Muralimohan, 2013b). The results on post oviposition period of *G. nephantidis* was similar to findings of Landge *et al.* (2009) who noted that the post-oviposition period of *B. hebetor* ranged from 1 to 9 days and 1 to 6 days on *C. cephalonica* and *O. arenosella*, respectively; it was prolonged 5.38 days on *M. testulalis* and shortest 3.07 days on *S. litura* for *B. hebetor* (Dabhi *et al.*, 2013); highest

on *E. kuehniella* had (1.9 ± 0.53 days) and shortest on *P. gossypiella* (0.78 ± 0.37) days for *B. hebetor* (Reda *et al.*, 2014).

4.1.4.5 Sex ratio

Based on the morphological characters, the adults were differentiated into their sexes. Adults emerged from laboratory mass culture during period of study, indicated that the preponderance of female. The sex ratio of male as to female was varied from 1: 2.60 to 1: 6.33 with an average of 1: 4.45 (Table-7). The present results are in accordance with Sreekanth and Muralimohan (2013a and 2013b) who reported that sex ratio was slightly male biased 0.14 males for *G. nephantidis*. The variation in sex ratio might be due to non viability of sperm or lack of fertilization under prevailing weather conditions in a particular locality, methodology adopted for the study, change in test insect and rearing media employed for the investigation. The present finding is more or less in agreement with Eylem and Adem (2005) who revealed that the mean sex ratio of *B. hebetor* (female per cent) was 45.99, 40.72 and 37.38 per cent in the 1, 5 and 10 day's age groups on *G. mellonella*, respectively and corresponding parameters were 45.09, 40.68 and 36.09 per cent in the 1, 5 and 10 day's age groups on *E. kuehniella*, respectively; 1: 5 for *A. sahyadrics* (Seetharama *et al.*, 2007); male ratio was on *C. Cephalonica* was 1: 1.32 and highest male ratio on *S. litura* was 1: 1.77 (Dabhi *et al*, 2013); Moreover, it was 1:3.5, 1: 3 and 1: 2 on 1st, 2nd and 3rd instar larva of carob moth larvae for *A. myeloenta* (Hosseini *et al.*, 2012).

4.1.4.6 Adult emergence

Perusal of data presented in Table-8, revealed that the per cent of adult emergence of *G. nephantidis* on *C. cephalonica* varied from 71.43 to 91.67 with an average of 83.06 ± 5.38 . The present findings cannot be compared as there is no information available pertaining to this aspect.

Table- 07: Sex ratio of <i>G. nephantidis</i> under laboratory conditions					
Sr. No.	Date of observation	No. of adults observed	Number of adults		Sex ratio (Male: Female)
			Sex		
			Male	Female	
1	30/03/2015	22	4	18	1: 4.50
2	31/03/2015	25	5	20	1: 4.00
3	01/04/2015	17	3	14	1: 4.67
4	02/04/2015	15	4	11	1: 2.75
5	03/04/2015	19	3	16	1: 5.33
6	04/04/2015	22	5	17	1: 3.40
7	06/04/2015	17	4	13	1: 3.25
8	07/04/2015	20	4	16	1: 4.00
9	01/05/2015	16	3	13	1: 4.33
10	01/05/2015	15	3	12	1: 4.00
11	08/05/2015	25	4	21	1: 5.25
12	09/05/2015	18	5	13	1: 2.60
13	10/05/2015	16	3	13	1: 4.33
14	11/05/2015	19	4	15	1: 3.75
15	14/05/2015	20	3	17	1: 5.67
16	15/05/2015	15	3	12	1: 4.00
17	16/05/2015	25	4	21	1: 5.25
18	01/06/2015	22	3	19	1: 6.33
19	01/06/2015	29	4	25	1: 6.25
20	01/06/2015	25	4	21	1: 5.25
Min.					1: 2.60
Max.					1: 6.33
Average					1: 4.45

Table-08: Adult emergence (%) of <i>G. nephandidis</i> under laboratory conditions				
Sr. No.	Period of study	No. of Cocoons observed	Total adults emerged (Male + Female)	Per cent adult emergence
1	28/03/2015 to 02/04/2015	13	11	84.62
2	29/03/2015 to 04/04/2015	22	19	86.36
3	30/03/2015 to 06/04/2015	27	20	74.07
4	31/03/2015 to 06/04/2015	18	15	83.33
5	02/04/2015 to 09 /04/2015	23	21	91.30
6	04/04/2015 to 09/04/2015	18	15	83.33
7	05/04/2015 to 12/04/2015	12	11	91.67
8	08/04/2015 to 12/04/2015	25	21	84.00
9	09/04/2015 to 15/04/2015	19	15	78.95
10	11/04/2015 to 18/04/2015	15	12	80.00
11	12/04/2015 to 19/04/2015	28	24	85.71
12	13/04/2015 to 19/04/2015	20	17	85.00
13	14/04/2015 to 21/04/2015	18	15	83.33
14	15/04/2015 to 21/04/2015	18	16	88.89
15	16/04/2015 to 24/04/2015	21	18	85.71
16	17/04/2015 to 25/04/2015	20	15	75.00
17	18/04/2015 to 25/04/2015	29	25	86.21
18	19/04/2015 to 28/04/2015	28	20	71.43
19	20/04/2015 to 28/04/2015	25	21	84.00
20	21/04/2015 to 18/04/2015	23	18	78.26
Min.				71.43
Max.				91.67
Av. $\pm$ S. D.				83.06 $\pm$ 5.38

4.1.4.7 Adult longevity

The data presented in Table-6, indicated that the male longevity of *G. nephantidis* on *C. cephalonica* varied from 9.0 to 19.00 days with an average of 13.77 ± 3.05 days, while the female longevity varied from 21.0 to 33.0 days with an average of 26.40 ± 3.39 days. More or less similar reports are made by Gordh (1976) who observed that the mean longevity of mated *G. gallicola* female was 62.43 ± 8.48 days; 6.1 ± 2.8 and 13.1 ± 1.26 day for male and female *G. natalensis*, respectively (Conlong *et al.*, 1988); mated females provided with host was 7.2 ± 0.6 days and mated host-deprived females lived for about 7.7 ± 0.5 days. While, in case of the mean longevity varied from 5.7 ± 0.6 to 7.7 ± 0.4 days for mated host-provided females (Witethom and Gordh, 1994); mated females were 6.73 ± 1.53 and 15.20 ± 2.04 days and while unmated females were 6.00 ± 1.46 and 15.20 ± 2.10 days for the starved and honey solution feeding adults, respectively for *G. legneri* (Shoeb *et al.*, 2005); large size adult female had 41.90 ± 5.86 days and small size adult female exhibited 38.40 ± 4.58 days for *G. nephantidis* (Sreekanth and Muralimohan, 2013b)

The present investigation on adult longevity of *G. nephantidis* is akin to Conlong *et al.* (1988) who noted that the *G. natalensis* males lived for 6.1 ± 2.8 days and the females lived for 13.1 ± 1.26 days; female of *A. sahyadrics* lived 66.48 ± 3.66 days with an with a range of 11 to 128 days and the male longevity was 7.96 ± 0.30 days with a range of 5 to 15 days (Seetharama *et al.*, 2007); male and female longevity of *Elasmus steffani* (Viggiani) on honey-water food source was 88.5 ± 16.4 and 32.6 ± 7.4 days, respectively (Redolfi and Campos, 2010); male longevity was shorter on *S. litura* (5.09 days) and prolonged on *C. cephalonica* (9.33 days), while female longevity was prolonged on *C. cephalonica* (31.76 days) and shorter on *S. litura* (16.02 day) for *B. hebetor* (Dabhi *et al.*, 2013); female longevity of *B. hebetor* was 20.00 ± 0.86 days and ranged from 15 to 29 days and male longevity was

Table- 09: Entire lifespan of <i>G. nephantidis</i> under laboratory conditions		
Sr. No.	Total life cycle (Days)	
	Female	Male
1	37	27
2	39	22
3	40	26
4	42	29
5	39	27
6	44	24
7	34	25
8	33	24
9	37	28
10	39	24
11	36	31
12	46	28
13	44	23
14	40	28
15	37	31
16	40	30
17	36	21
18	39	25
19	47	25
20	38	33
21	41	28
22	37	33
23	38	21
24	42	32
25	41	30
26	39	28
27	38	22
28	36	30
29	42	28
30	39	26
Min.	33	21
Max.	47	33
Av. ± S.D.	39.33 ± 3.24	26.97 ± 3.45

Table- 10: Life cycle of <i>G. nephantidis</i> under laboratory conditions when reared on <i>C. cephalonica</i>					
Sr. No.	Particulars	No. observed	Period (Days)		
			Min.	Max.	Av. $\pm$ S.D.
1	Incubation period (Days)	30	1	3	2.10 $\pm$ 0.71
2	Hatching percentage	20	75.71	95.24	87.03 $\pm$ 5.86
3	Larval period (Days)	30	3	5	4.03 $\pm$ 0.81
4	Pre-cocoon period (Days)	30	1	2	1.53 $\pm$ 0.51
5	Cocoon period (Days)	30	4	7	5.53 $\pm$ 1.00
6	Pre-oviposition period (Days)	30	3	6	4.70 $\pm$ 0.95
7	Oviposition period (Days)	30	13	25	18.63 $\pm$ 3.27
8	Post-oviposition period (Days)	30	2	5	2.80 $\pm$ 0.76
9	Adult emergence (%)	20	71.43	91.67	83.06 $\pm$ 5.38
10	Sex ratio (Male: Female)	20	1: 2.60	1: 6.33	1: 4.45
11	Adult longevity (Days)				
	Male	30	9	19	13.77 $\pm$ 3.05
	Female	30	21	33	26.40 $\pm$ 3.39
12	Total life cycle (Days)				
	Male	30	21	33	26.97 $\pm$ 3.45
	Female	30	33	47	39.33 $\pm$ 3.24
13	Fecundity (Nos.)	30	47	94	72.57 $\pm$ 13.41
14	Temperature ($^{\circ}$ C)	-	22.60	28.30	25.51 $\pm$ 1.71
15	Relative humidity (%)	-	61.10	72.50	64.55 $\pm$ 2.97

14.40 $\pm$ 0.638 days and it was ranged from 8 to 20 days for (Shah *et al.*, 2014); female longevity of *B. hebetor* was highest on *G. mellonella* 19.11 $\pm$ 1.8 days and lowest on *C. cephalonica* 9.7 $\pm$ 0.71 days and the male longevity was prolonged on *G. mellonella* 9.2 $\pm$ 0.66 days and shorter on *E. kuehniella* as 7.6 $\pm$ 0.6 days (Farag *et al.*, 2015).

4.1.4.8 Fecundity

The fecundity varied from 47 to 94 eggs per female with an average of 72.57 $\pm$ 13.41 eggs per female (Table-6). The present findings are corroborated with reports of Dharmaraju (1952) who found that single female laid about 10 to 14 eggs per day; 42.07 $\pm$ 1.38 eggs on *P. gossypiella* and 44.67 $\pm$ 10.59 eggs on *E. kuehniell* for *G. legneri* (Shoeb *et al.*, 2005). Moreover, eggs laid by *G. nephantidis* ranged from 66.50 $\pm$ 9.52 to 89.15 $\pm$ 7.63 eggs. The discrepancy in fecundity of *G. nephantidis* perhaps this might be due to different host insects used and seasonal fluctuation in temperature and other weather parameters in study area.

The result pertaining to fecundity of *G. nephantidis* is more or less similar to Seetharama *et al.* (2007) who indicated that the fecundity of *A. sahyadrics* was 53.64 $\pm$ 3.06 eggs; 141 to 577 and 13 to 59 on *cephalonica* and *O. arenosella*, respectively for *B. hebetor* (Landge *et al.*, 2009); fecundity of *B. hebetor* was maximum on *C. cephalonica* (154.25 eggs) and minimum on *S. litura* (73.63 eggs) for *B. hebetor* (Dabhi *et al.*, 2013); fecundity of *B. brevicornis* was highest on *G. mellonella* 268.88 $\pm$ 19.65 and lowest on *E. kuehniella* 71.1 $\pm$ 7.15 eggs (Reda *et al.*, 2014); fecundity of *B. brevicornis* on *P. interpunctella* was 2.42 and 13.65 eggs on 4th and 5th instar larvae, respectively and 4 and 13 eggs on 2nd and 3rd instar larvae, respectively (Malesios and Prophetou, 2014); fecundity of *B. hebetor* was highest on *G. mellonella* (395.11 $\pm$ 79.7 eggs) and lowest on *C. cephalonica* 56.0 $\pm$ 6.3 eggs (Farag *et al.*, 2015).

4.1.5 Total life cycle

Looking to the data (Table-9 to 10), it can be seen that the duration of total life cycle varied from 21 to 33 days with an average of 26.97 ± 3.45 days for males; 33 to 47 days with an average of 39.33 ± 3.24 days as in case of female. The present studies on total life cycle of *G. nephantidis* is more or less in accordance with reports of Seetharama *et al.* (2007) who indicated that the total life cycle of *A. sahyadrics* was 31.36 ± 0.67 days and with a range of 22 to 42 days; female life cycle prolonged on *C. cephalonica* (44.30 days) and shortest on *S. litura* (27.64 days). While, male life cycle was increased on *C. cephalonica* as 15.28 days and decreased on *S. litura* as 8.72 days (Dabhi *et al.*, 2013).

4.2 Parasitic potential of *G. nephantidis* on *C. cephalonica*

The investigation on parasitic potential of *G. nephantidis* on *C. cephalonica* was carried out in the P.G. Research Laboratory, Department of Entomology, N.M. College of Agriculture, Navsari Agricultural University, Navsari under the laboratory condition at 25.51 ± 1.71 °C temperatures and 64.55 ± 2.97 per cent relative humidity during 2014-15. The results obtained during the present studies are presented in Table-11 and discussed hereunder [Plate-XI to XVIII].

4.2.1 Parasitic behaviour of *G. nephantidis* on *C. cephalonica*

The parasitic potential of *G. nephantidis* on larvae of *C. cephalonica* revealed that the larval stage of host insect, *C. cephalonica* was offered to adults of parasitoid; *G. nephantidis* alone, the parasitoid inject venom and paralyzed the host larva within 2 to 3 hours after release. Adults of *G. nephantidis* started biting and preparing the larvae of *C. cephalonica* for oviposition. The female inspect the host for about 20 to 25 seconds. It moves its antenna and searches around larval body. The female immediately moves to the dorsum of the hosts thorax and attempts to attaching its mandibles to it. The parasitoid attempts to move to the head of the host larva and sting between the head and thorax which was in the vicinity of the sub oesophageal ganglion. The larva remains passive at first and then attempts to keep away the parasitoid,



Plate- XI: Adult of *G. nephantidis* feeding on *Corcyra* larva



Plate-XII: Larvae of *G. nephantidis* feeding on *Corcyra*

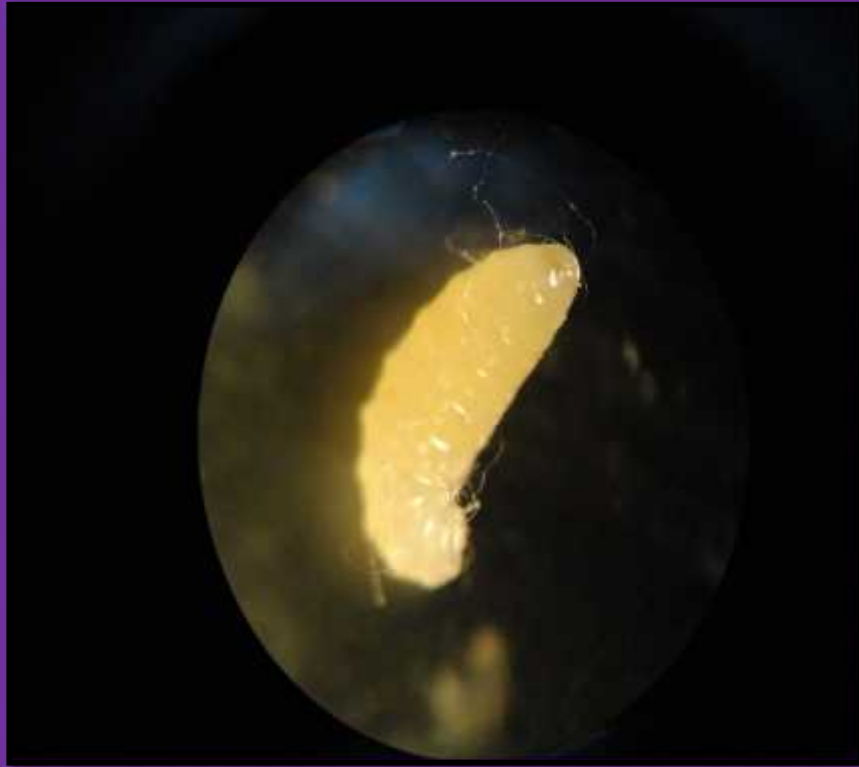


Plate-XIII: Spinning of cocoon by larvae of *G. nephantidis*



Plate-XIV: Eggs loaded larvae of *Corcyra* placed on paper stripes for formation of cocoon



Plate-XV: Mature larvae of *G. nephantidis* transferred on to accordion type paper for cocoon formation



Plate-XVI: Cocoons of *G. nephantidis* on paper stripes



Plate-XVII: Paralyzed larvae of *Corcyra* by *G. nephantidis*



Plate-XVIII: Completely parasitized larvae of *Corcyra* by *G. nephantidis*

but it was useless. The female left the larva for a short time and returns to it for walking upon its back, moving its antenna endlessly for assessing size of the host and cleaning the external surface of the segment which was selected after examining with its mandibles. The female usually fed on haemolymph by cutting legs of the host and greedily licks it from wound which cuts by mandibles (Plate-XI). Moreover, the larva was moved by the female to find a suitable position. The feeding takes about 3 to 4 minutes. They deposit both single and multiple-egg clutches on their hosts. The time taken from paralysis to eggs laying was about 35 to 50 minutes and during this time some paralyzed larvae were moved to a better position. The time for depositing a single egg varied from 2 to 3 minutes. The paralyzed larva lasted for about 2 hours, after which it begins to change its position. After the egg laying process, the female showed high degree of parental care to protect further eggs laying on same host as well as entry of any other parasitoid in the vicinity of parasitized larvae. The most preferred host segments for egg laying of parasitoid was 5th to 6th abdominal segments of host larvae but there was no egg laying on first and last abdominal segments of the host.

4.2.2 Parasitic potential of *G. nephantidis* on *C. cephalonica*

4.2.2.1 Number of parasitized larvae

Perusal of data presented in Table-11 and Plate-XII to XVIII, on parasitic potential of *G. nephantidis* on *C. cephalonica* revealed that the number of larvae parasitized by adult parasitoids under laboratory condition varied from 4.0 to 8.0 with an average of 6.07 ± 1.55 . This findings are in accordance with Pillai and Bhat (1986) who reported that *G. nephantidis* preferred fifth and sixth instar larvae of *O. arenosella*; the mean number of host larvae parasitized by female of *G. thailandensis* were 1.6 ± 0.1 with 13.3 ± 1.2 per cent (Witethom and Gordh, 1994); total number of paralyzed host larvae by the female of *G. legneri* was 22.67 ± 4.01 for *E. kuehniella* and 22.20 ± 4.23 for *P. gossypiella* larvae and on total number of host larvae parasitized by female of *G. legneri*

Table- 11: Parasitic potential of <i>G. nephantidis</i> under laboratory conditions			
Sr. No.	Number of Corcyra larvae parasitized	Clutch size (No. of eggs/larvae)	Eggs laid on host body part
1	7	9	+
2	5	13	++
3	4	8	+
4	8	11	++
5	7	9	+++
6	4	14	++
7	6	7	+
8	8	9	+
9	4	10	++
10	6	6	+++
11	7	9	++
12	8	11	++
13	8	8	++
14	4	9	+
15	6	8	+++
16	8	10	++
17	5	9	+
18	4	6	++
19	5	10	++
20	7	7	+
21	4	13	++
22	8	6	+
23	5	8	+
24	8	10	++
25	6	8	+++
26	4	11	++
27	8	8	+
28	5	9	+
29	7	6	+++
30	6	7	++
Min.	4	6	-
Max.	8	14	-
Av. $\pm$ S.D.	6.07 $\pm$ 1.55	8.97 $\pm$ 2.09	-
Notations: + = The maximum eggs were laid on 3 to 4 th abdominal segments + + = The maximum eggs were laid on 5 to 6 th abdominal segments +++ = The maximum eggs were laid on 7 to 8 th abdominal segments			

was 8.67 ± 2.10 on *E. kuehniella* larvae and 7.80 ± 2.10 on *P. gossypiella* larvae (Shoeb *et al*, 2005). The present findings are corroborated with findings of Redolfi and Campos (2010) who showed that the number of parasitized host's larvae per day by *E. steffani* was ranged from 1 to 4 with an average of 1.3 ± 0.1 per day.

4.2.2.2 Clutch size

The clutch size of *G. nephantidis* presented in the Table-11 and result indicated that the clutch size varied from 6.0 to 14.0 eggs per host larva with an average of 8.97 ± 2.09 eggs per host larva. The present findings are more or less agreed with reports of Witethom and Gordh (1994) who reported that the clutch size was 2 to 13 eggs per host larva for *G. thailandensis*. Further, Seetharama *et al.* (2007) stated that the clutch size ranged from 3 to 35 eggs per host larvae (Av. 17.52 ± 1.11); 141 to 577 and 13 to 59 eggs per larva of host *C. cephalonica* and *O. arenosella*, respectively for *B. hebetor* (Landge *et al.*, 2009); clutch size of *E. steffani* was 4.4 ± 0.4 eggs/per host larva (Redolfi and Campos, 2010).

The variation in parasitic potential of *G. nephantidis* on *C. cephalonica* might be due to different parasitoid and host insects used in their experiment, prevailing weather conditions in a particular locality and methodology employed for the investigation.

4.3 Relative toxicity of various insecticides against *G. nephantidis*

A laboratory experiment was conducted in the Bio-control Laboratory, Department of Entomology, N. M. College of Agriculture, Navsari Agricultural University, Navsari by using Completely Randomized Design (C.R.D.) with ten treatments repeated thrice during the year 2015-16. The data in terms of percentage of mortality recorded at 12, 24, 48 and 72 hours after insecticidal application are presented in Table-12 and depicted in Fig- 1 to 2, and discussed as hereunder.

Table- 12: Relative toxicity of different insecticides against adults of <i>G. nephantidis</i> under laboratory condition (2015-16)								
Treat. No.	Treatment detail	Conc. (%)	Mean per cent mortality at different intervals				Pooled	Toxicity Rating
			12 HAT	24 HAT	48 HAT	72 HAT		
T₁	Indoxacarb 15.8 % EC	0.01	18.42b (10.00)	30.98c (26.67)	37.20cd (36.67)	43.05c (46.67)	32.41 bcd (30.00)	2
T₂	Emamectin benzoate 5% SG	0.0025	26.55c (20.00)	35.20de (33.33)	46.90e (53.33)	54.76d (66.67)	40.85 cde (43.33)	2
T₃	Chlorpyriphos 20 % EC	0.05	28.76c (23.33)	39.21ef (40.00)	52.75f (63.33)	77.50e (93.33)	49.55 ef (55.00)	3
T₄	Quinalphos 25 % EC	0.05	26.55c (20.00)	37.20 ef (36.67)	48.82ef (56.67)	58.98d (73.33)	42.88 de (46.67)	2
T₅	Flubendiamide 39.35 % SC	0.0096	18.42b (10.00)	28.76bc (23.33)	33.19c (30.00)	39.21c (40.00)	29.89 bc (25.83)	2
T₆	Spinosad 45 % SC	0.002	12.45b (6.67)	23.84b (16.67)	26.55b (20.00)	30.98b (26.67)	23.45 b (17.50)	1
T₇	Profenofos 50 % EC	0.075	26.55c (20.00)	30.98cd (26.67)	41.13d (43.33)	52.75d (63.33)	37.85 cd (38.33)	2
T₈	Dichlorvos 76 % EC	0.05	41.13d (43.33)	48.82g (56.67)	66.11g (83.33)	89.44f (100.00)	61.37 g (70.83)	3
T₉	Triazophos 40 % EC	0.05	30.98c (26.67)	41.13f (43.33)	61.19g (76.67)	89.44f (100.00)	55.68 fg (61.67)	3
T₁₀	Control (Water spray)	-	0.91a (0.00)	0.91a (0.00)	0.91a (0.00)	0.91a (0.00)	0.91a (0.00)	1
S. Em ± (T)			2.21	1.93	1.77	2.39	4.02	
(PxT)			-	-	-	-	2.09	
C.D. at5% (T)			6.53	5.71	5.22	7.05	11.68	
(PxT)			-	-	-	-	NS	
C.V. (%)			16.66	10.59	7.40	7.72	9.68	

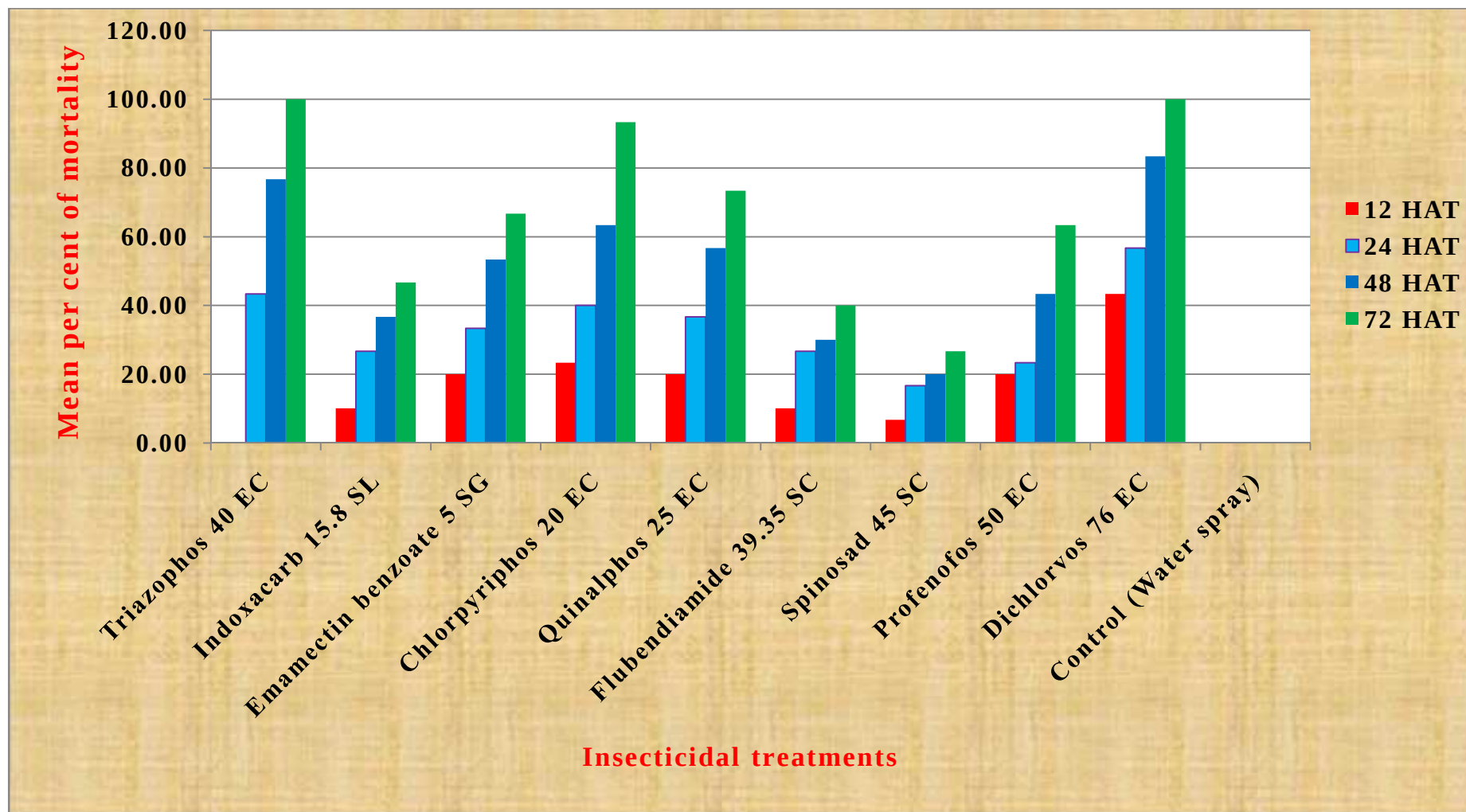


Fig.1: Relative toxicity of different insecticides against adults of *G. nephandidis* under laboratory condition

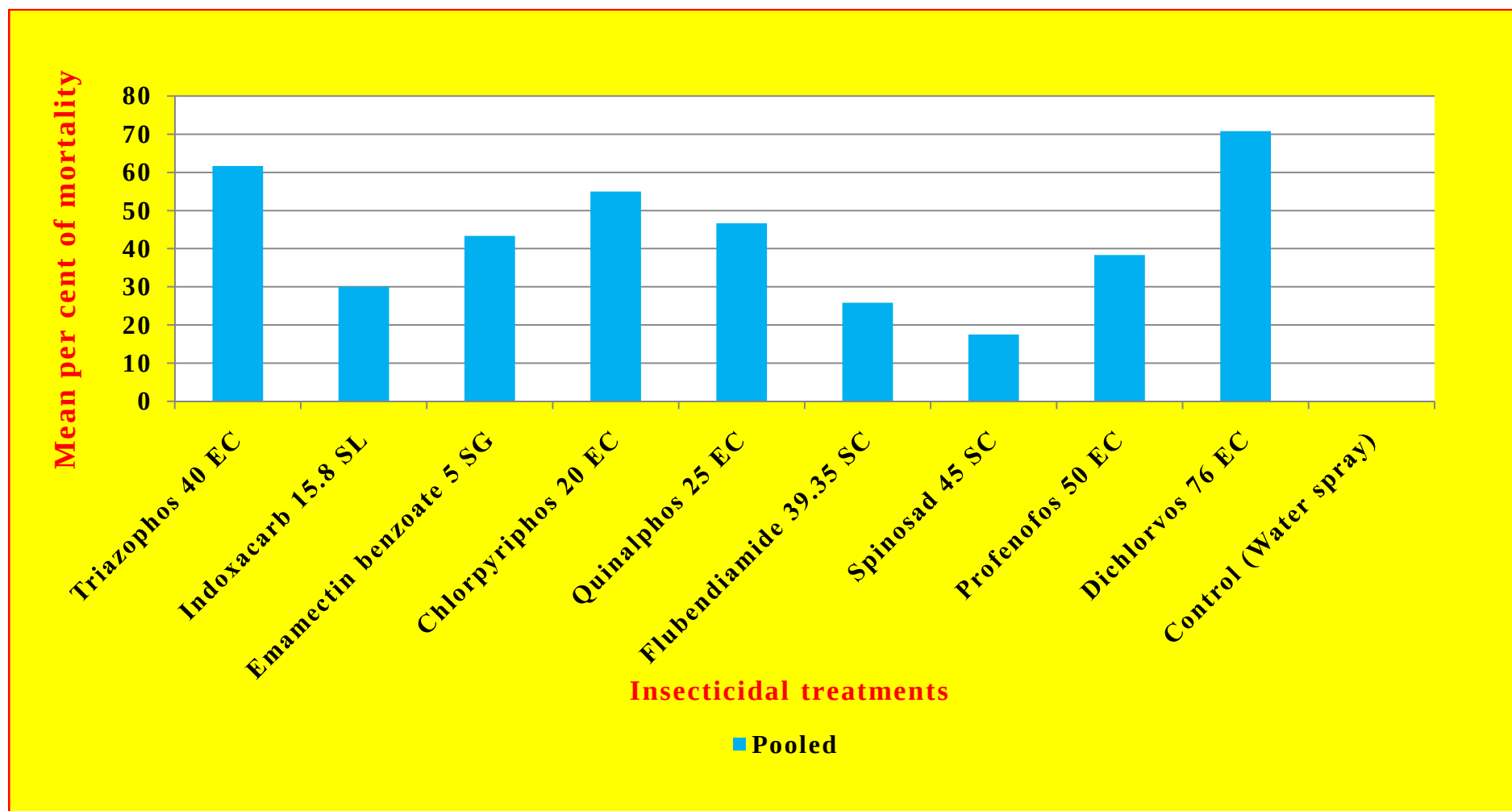


Fig.2: Relative toxicity of different insecticides against adults of *G. nephantidis* under laboratory condition (Pooled)

The perusal of the mortality data obtained at 12 hrs after treatments indicated that no adult mortality was recorded in control treatment (water spray). The treatment of spinosad 0.002 per cent recorded the lowest adult mortality (6.67%) which was at par with flubendiamide 0.0096 per cent (10.00%) and indoxacarb 0.01 per cent (10.00 %). The treatment of profenofos 0.075 per cent, emamectin benzoate 0.0025 per cent and quinalphos 0.05 per cent had equal adult mortality (20.00%). Moreover, remaining insecticides viz., chlorpyriphos 0.05 per cent, triazophos 0.05 per cent and dichlorvos 0.05 per cent showed 23.33, 26.67 and 43.33 per cent, respectively.

It can be seen from the data obtained at 24 hrs that no adult mortality occurred in control treatment (0.00%). The treatment of spinosad 0.002 per cent showed lowest mortality (16.67%) which was statistically at par with flubendiamide 0.0096 per cent (23.33%) and it was followed by indoxacarb 0.01 per cent (26.67%), profenofos 0.075 per cent (26.67%), emamectin benzoate 0.0025 per cent (33.33%), quinalphos 0.05 per cent (36.67%), chlorpyriphos 0.05 per cent (40.00%), triazophos 0.05 per cent (43.33%) and dichlorvos 0.05 per cent (56.67%).

The data on per cent adult mortality at 48 hrs after treatment indicated that treatment of spinosad 0.002 per cent exhibited minimum adult mortality (20.00%). This was followed by flubendiamide 0.0096 per cent (30.00%), indoxacarb 0.01 per cent (36.67%), profenofos 0.075 per cent (43.33%), emamectin benzoate 0.0025 per cent (53.33%) and quinalphos 0.05 per cent (56.67%). The toxicity of remaining insecticides in ascending order was chlorpyriphos 0.05 per cent (63.33 %) < triazophos 0.05 per cent (76.67%) < dichlorvos 0.05 per cent (83.33%).

At 72 hrs after exposure, control treatment recorded no any adult mortality. This was followed by spinosad 0.002 per cent (26.67%) and flubendiamide 0.0096 per cent (40.00%). The toxicity of remaining insecticides in ascending order was indoxacarb 0.01 per cent (46.67%) <

profenofos 0.075 per cent (63.33%) < emamectin benzoate 0.0025 per cent (66.67%) < quinalphos 0.05 per cent (73.33 %) < chlorpyriphos 0.05 per cent (93.33 %) except triazophos 0.05 per cent and dichlorvos 0.05 per cent exhibited cent per cent adult mortality.

Looking to the pooled analysis the data revealed that all treatments under the investigation showed significant mortality to adults of *G. nephantidis* except control treatment (0.00%). Moreover, the treatment of spinosad 0.002 per cent (17.50%) was at par with flubendiamide 0.0096 per cent (25.83%) and indoxacarb 0.01 per cent (30.00%) and it was followed by profenofos 0.075 per cent (38.33%), emamectin benzoate 0.0025 per cent (43.33%), quinalphos 0.05 per cent (46.67%), chlorpyriphos 0.05 per cent (55.00%), triazophos 0.05 per cent (61.67%) and dichlorvos 0.05 per cent (70.83%).

The ascending order of toxicity of different insecticides to adults of *G. nephantidis* were spinosad 0.002 per cent < flubendiamide 0.0096 per cent < indoxacarb 0.01 per cent < profenofos 0.075 per cent < emamectin benzoate 0.0025 per cent < quinalphos 0.05 per cent < chlorpyriphos 0.05 per cent < triazophos 0.05 per cent < dichlorvos 0.05 per cent. The ANOVA of pooled analysis of data on per cent adult mortality over period revealed that the interaction (Period x Treatment) was found to be non-significant indicating consistent performance of various treatments over period of observation. Based on the pooled data, the ranking to the various insecticides were made and presented hereunder (Sterk *et al.*, 1999).

Score	Category	Perceived insecticides
1	Harmless (<25% mortality)	Spinosad 45% SC
2	Slightly harmful (25-50% mortality)	Indoxacarb 15.8% EC, Emamectin benzoate 5% SG, Quinalphos 25% EC Flubendiamide 39.35% SC, Profenofos 50% EC

Score	Category	Perceived insecticides
3	Moderately harmful (51-75% mortality)	Triazophos 40% EC, Dichlorvos 76% EC, Chlorpyriphos 20% EC,
4	Harmful (>75% mortality)	Nil

From the above all results, it is ascertained that there was no insecticide under testing found totally safe except control treatment (water spray) to the adult of *G. nephantidis*. However, spinosad 45 per cent SC was comparatively harmless to the adults. Moreover, indoxacarb 15.8 per cent EC, emamectin benzoate 5 per cent SG, quinalphos 25 per cent EC, flubendiamide 39.35 per cent SC and profenofos 50 per cent EC were slightly harmful. Moreover, the treatment of triazophos 40 per cent EC, dichlorvos 76 per cent EC and chlorpyriphos 20 per cent EC were moderately harmful, while none of insecticide was grouped as harmful to the adults of *G. nephantidis*.

Present findings are more or less in accordance with the findings of past workers viz., Sundaramurthy (1980) recorded more or less similar observations and revealed that diflubenzuron was applied once at 2.5 to 20g ai/10 litres of water to coconut palms found safer against to *Perisierola nephantidis* Mues. Whereas, Bhushan and Azam (1990) who reported that the deltamethrin was the most toxic insecticide to both parasitoids viz., *G. nephantidis* and *B. hebetor* at 0.0000926 and 0.0000626 per cent LC₅₀ value, respectively and it was followed by cypermethrin (0.000107 and 0.0000693%), permethrin (0.000284 and 0.000820%) and fenvalerate (0.000505 and 0.000126%). Among the tested insecticides, monocrotophos 0.04 per cent and chlorpyriphos 0.04% per cent were very toxic to all the stages of *B. brevicornis*, *G. nephantidis* and *T. pupivora* under laboratory condition (Patil *et al.*, 1990).

The findings are in conformity with the results reported by Dhawan (2000) who noted that the quinalphos (500g ai/ha), chlorpyriphos (1000g ai/ha) and chlorpyriphos methyl (1000g ai/ha)

were found more toxic to the larvae of *Chrysoperla carnea* (Stephens) and recorded 90.7 to cent per cent mortality. Later on, Srinivasan and Sundarababu (2000) indicated that the quinalphos 0.05 per cent was toxic to larvae of *C. carnea*. Consoli *et al.* (2001) who noticed that the lufenuron (15 g ai/100 litre water), triflumuron (25 g ai/100 litre water) and spinosad (48 g ai/100 litre water) were harmful and tebufenozide (12 g ai/100 litre water) was harmless to *Trichogramma galloi* Zucchi which differed with the present investigation on spinosad as it was harmless to adults of *G. nephantidis*. However, Abida *et al.* (2004) who found that *Bacillus thuringiensis*, spinosad, thiodicarb and indoxacarb exhibited safety to adults of *T. chilonis* and *C. carnea* which disagreed with above worker as it existed as slightly harmful to adults of *G. nephantidis*. Varghese and Beevi (2004) reported that chlorpyrifos had the lowest LC₅₀ value i.e. 0.0017 and found to be the most toxic to larvae of *C. carnea*, while triazophos found less toxic (LC₅₀ 0.0349) which not in support to present finding as triazophos 40 EC found more toxic to adults of *G. nephantidis* and caused the highest mortality. Rashad *et al.* (2005) reported that the chlorpyrifos 40 EC and profenofos 50 EC were found to be the most toxic to the adults of *B. hebetor* and present investigation revealed that profenofos 50 EC had slightly toxic to adults of *G. nephantidis*. According to Nalini and Manickavasagam (2011), profenofos caused cent per cent mortality within 1 hour in both *Aenasius bambawalei* (Hayat) and *Aenasius advena* (Compere) and it was slightly corroborated with above worker as found slightly toxic to adults of *G. nephantidis*. The present investigation are agreed with Ahmad *et al.* (2012) who reported that the spinosad 0.01 per cent showed less toxicity to the *T. chilonis* in oviposition preference.

The present investigations are akin to findings of Hooshang *et al.* (2012) who suggested that the indoxacarb had slightly toxic to *H. hebetor*. Chaturvedi (2014) reported that the chlorpyrifos 50 per cent EC noted as harmful to *Carcella illota* (Curran). The present

findings are in line with Karthik *et al.* (2015) who observed that the least mortality of *C. blackburni* adults was exhibited in the lower dose of emamectin benzoate 5 SG (7 g a.i/ha) which showed 13.33, 23.33 and 33.33 per cent mortality at 6, 12 and 24 HAT, respectively and spinosad at 75 g a.i/ha registered the mortality percentage of 36.67, 46.67 and 56.67 at 6, 12 and 24 HAT, respectively. Dilbar *et al.* (2015) reported that the emamectin benzoate, lufenuron, and imidacloprid were found safer to *T. chilonis* and recorded more than 50 per cent adult emergence. The findings of above workers support the present investigation while discrepancy in relative toxicity of various insecticides against adults of *G. nephantidis* perhaps might be due to variation in test insect, tested insecticides, food on which the insect reared, adopted methodology for their investigation and prevailing ecological conditions.

4.4 Natural occurrence of larval parasitoid on black headed caterpillar, *O. arenosella* under Navsari condition.

During the present investigation on naturally occurrence of larval parasitoids of black headed caterpillar under Navsari condition revealed that two larval parasitoids viz., *G. nephantidis* and *H. hebetor* were recorded (Plate-XIX to XXIII) and identified from NBAIR, Bengaluru (Karnataka). Among the two parasitoids, *G. nephantidis* was the dominant species thought out the year.

Looking to the data presented in Table-13.1 to 13.2 and Fig.-3 to 5 revealed that the highest per cent of parasitism by *G. nephantidis* and *H. hebetor* was recorded during 2nd fortnight of May (17.69 and 15.65%) and followed by the 1st fortnight of May (17.58 and 13.19%) for the both parasitoids, respectively. While, lowest per cent of parasitism by *G. nephantidis* was noticed during the 1st fortnight of the October (2.23%) thereafter gradual increase in the parasitism was observed up to 2nd fortnight of December (14.88%). In case of *H. hebetor*, the lowest per cent of parasitism was recorded during the 1st fortnight of the August to 1st fortnight of the September



Plate-XIX: Coconut leaf damaged by black headed caterpillar, *O. arenosella* under Navsari condition



Plate-XX: Severe damage made by black headed caterpillar, *O. arenosella* under Navsari condition



Plate-XXI: Silken galleries made by larvae of *O. arenosella* on coconut leaflet



Plate-XXII: Collection of larvae of *O. arenosella* during survey programme in plastic vial



Adult of *G. nephantidis*



Adult of *H. hebetor*

Plate-XXIII: Larval parasitoids identified in coconut ecosystem on black headed caterpillar under Navsari condition

(00.00%) after that the fluctuations were occurred in per cent parasitism. Moreover, the highest number of *O. arenosella* larvae were parasitized by *G. nephantidis* and *H. hebetor* during the 2nd fortnight of May (52 and 46 larvae) and followed by the 1st fortnight of May (48 and 36 larvae) for the both parasitiods, respectively and lowest number of the larvae were parasitized by *G. nephantidis* during the 2nd fortnight of the September to 1st fortnight of the October (4 larvae) later on number of larvae parasitized was increased up to 2nd fortnight of December (18 larvae). However, parasitism by *H. hebetor* was found to be nil from 1st fortnight of the August to 1st fortnight of the September.

The perusal of data presented in Table-14 indicated that the total number of adults emerged from host larvae for *G. nephantidis* and *H. hebetor* were maximum during the 2nd fortnight of May (347 and 213 adults) followed by the 1st fortnight of May (312 and 149 adults) for the both parasitiods, respectively and the total numbers of adults were emerged from host larvae for *G. nephantidis* was less during the 2nd fortnight of the August (25 adults) in case of *H. hebetor* it was nil during the 1st fortnight of the August to 1st fortnight of the September. Moreover, the number of adults of *G. nephantidis* emerged from single larva was maximum during the 2nd fortnight of the September (8.80 adults/ larva) followed by 2nd fortnight of the December (7.94 adults/ larva) and it was minimum during the 2nd fortnight of the August (4.17 adults/ larva). While in case of *H. hebetor* the total adults emerged from single larva was highest during the 2nd fortnight of the February (7.57 adults/ larvae) followed by 1st fortnight of the February (6.70 adults/ larva) and it was lowest during the from 1st fortnight of the August to 1st fortnight of the September (0 adults/ larva).

Table-13.1: Occurrence of larval parasitoids on black headed caterpillar, <i>O. arenosella</i> under Navsari condition							
Fortnight	No. of larvae collected from 20 selected palms on 5 lower leaflets	No. of <i>O. arenosella</i> larvae parasitized by <i>G. nephantidis</i>	Per cent parasitisation by <i>G. nephantidis</i>	No. of <i>O. arenosella</i> larvae parasitized by <i>H. hebetor</i>	Per cent parasitisation by <i>H. hebetor</i>	Total no. of <i>O. arenosella</i> larvae parasitized	Per cent parasitisation by both parasitoids
10-01-15	127	7	5.51	12	9.45	19	14.96
31-01-15	113	9	7.96	10	8.85	19	16.81
01-02-15	125	12	9.60	8	6.40	20	16.00
15-02-15	137	17	12.41	7	5.11	24	17.52
07-03-15	124	16	12.90	7	5.65	23	18.55
22-03-15	149	21	14.09	13	8.72	34	22.82
05-04-15	231	36	15.58	21	9.09	57	24.68
24-04-15	252	41	16.27	27	10.71	68	26.98
09-05-15	273	48	17.58	36	13.19	84	30.77
17-05-15	294	52	17.69	46	15.65	98	33.33
06-06-15	166	15	9.04	20	12.05	35	21.08
21-06-15	145	10	6.90	12	8.28	22	15.17
05-07-15	128	7	5.47	2	1.56	9	7.03
25-07-15	119	6	5.04	1	0.84	7	5.88

Table-13.2: Occurrence of larval parasitoids on black headed caterpillar, <i>O. arenosella</i> under Navsari condition							
Fortnight	No. of larvae collected from 20 selected palms on 5 lower leaflets	No. of <i>O. arenosella</i> larvae parasitized by <i>G. nephantidis</i>	Per cent parasitisation by <i>G. nephantidis</i>	No. of <i>O. arenosella</i> larvae parasitized by <i>H. hebetor</i>	Per cent parasitisation by <i>H. hebetor</i>	Total no. of <i>O. arenosella</i> larvae parasitized	Per cent parasitisation by both parasitoids
15-08-15	111	5	4.50	0	0.00	5	4.50
29-08-15	121	6	4.96	0	0.00	6	4.96
12-09-15	106	5	4.72	0	0.00	5	4.72
22-09-15	108	4	3.70	2	1.85	6	5.56
06-10-15	179	4	2.23	6	3.35	10	5.59
24-10-15	239	12	5.02	8	3.35	20	8.37
14-11-15	187	17	9.09	7	3.74	24	12.83
29-11-15	162	14	8.64	8	4.94	22	13.58
05-12-15	136	15	11.03	7	5.15	22	16.18
20-12-15	121	18	14.88	5	4.13	23	19.01

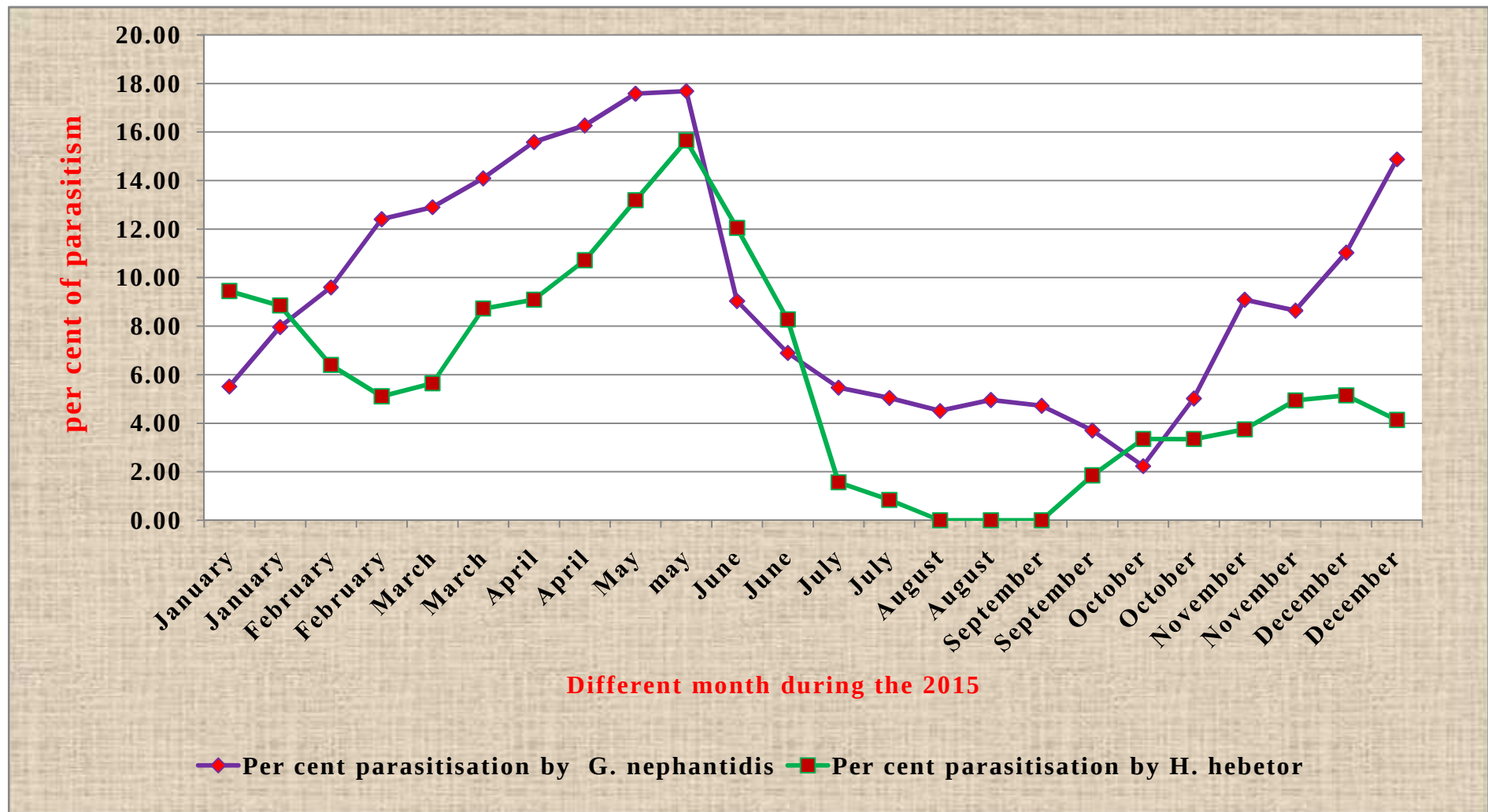


Fig.3: Per cent parasitization by larval parasitoids of the black headed caterpillar, *O. arenosella* under Navsari conditions

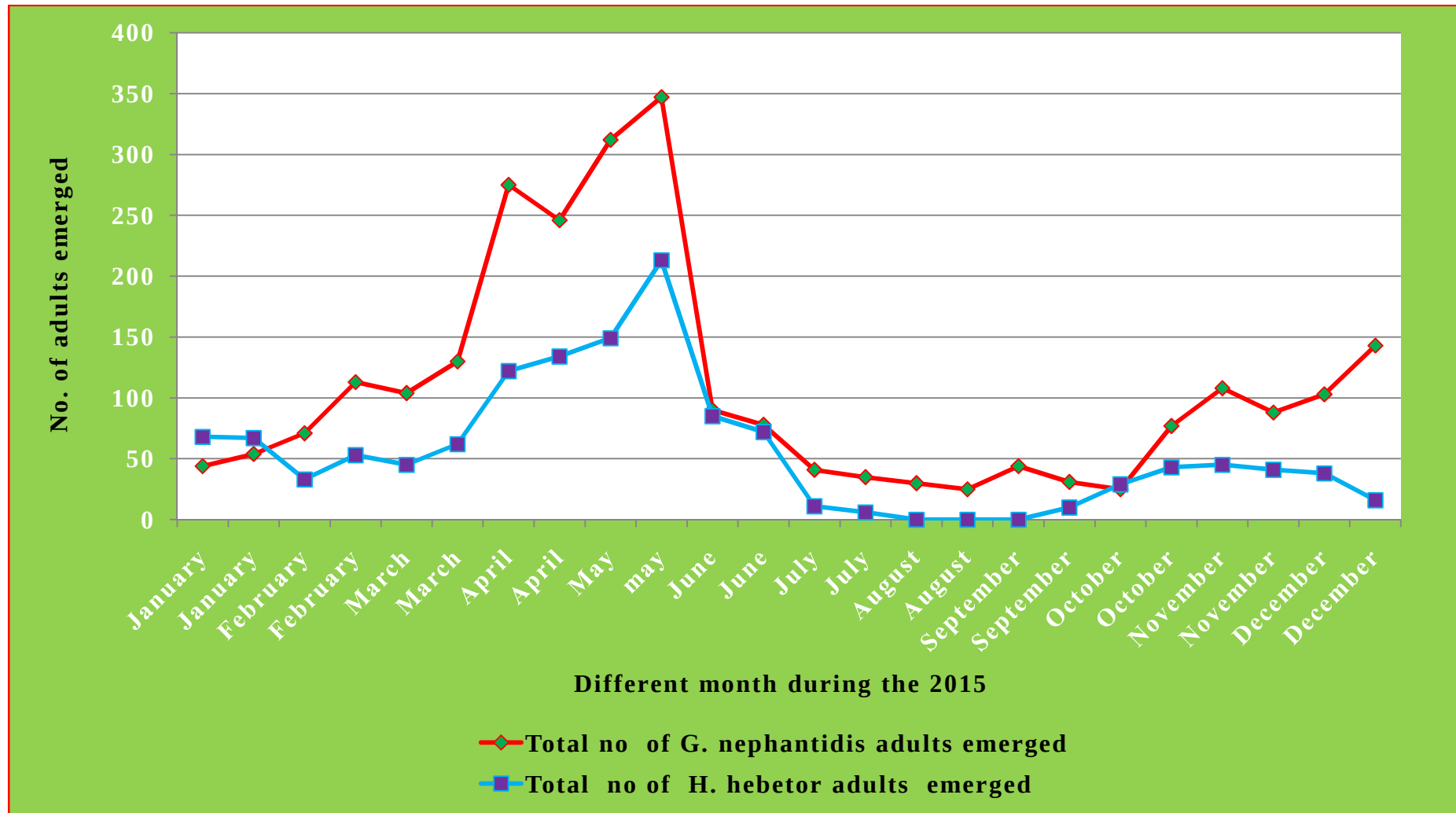


Fig. 4: Total number of adult parasitoids emerged from larvae of black headed caterpillar, *O. arenosella* under Navsari condition (2015).

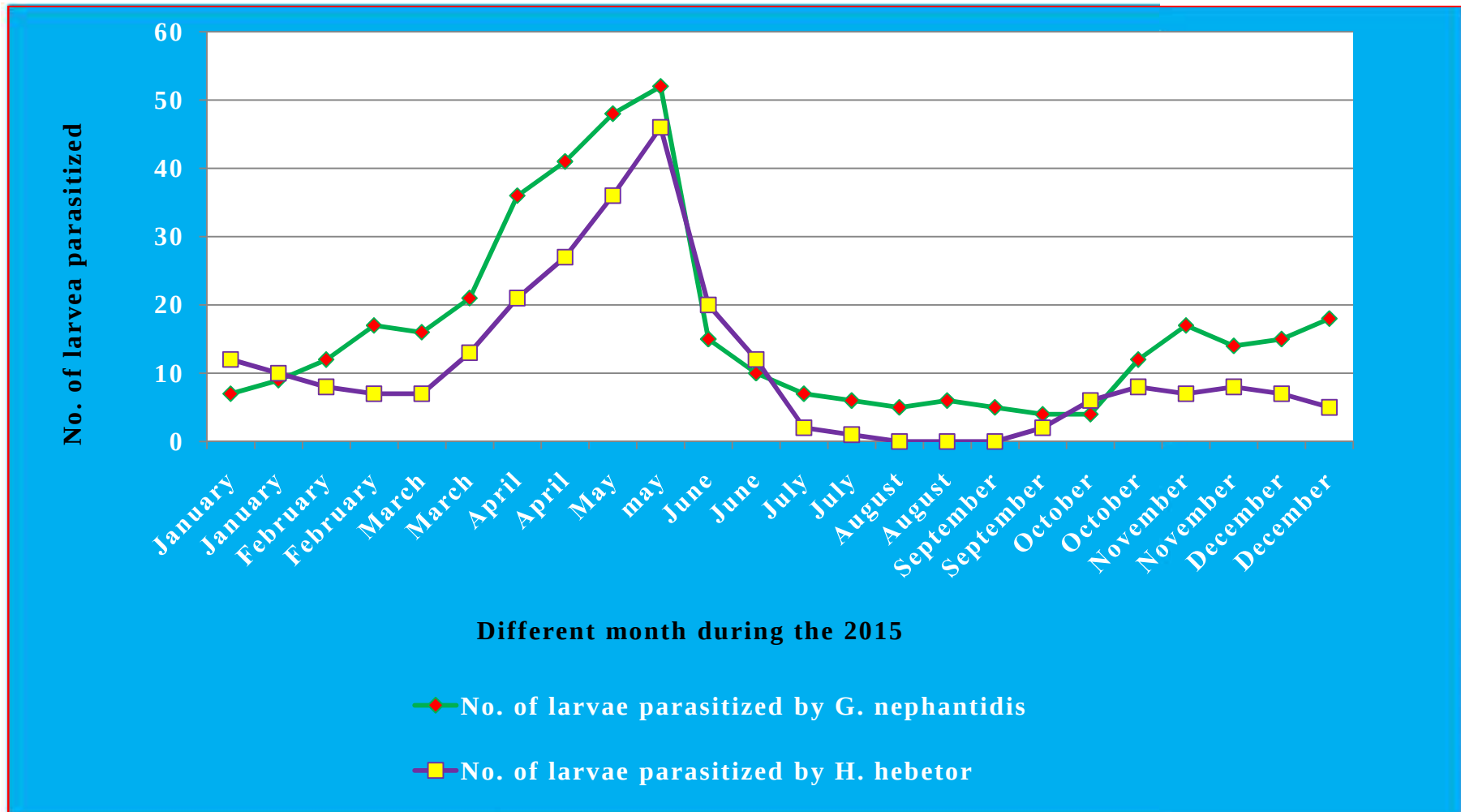


Fig.5: Total number of black headed caterpillar larvae parasitized by larval parasitoids under Navsari condition (2015)

Table-14: Adults of parasitoid emerged from <i>O. arenosella</i> under Navsari condition.						
Fortnight	No. of <i>O. arenosella</i> larvae parasitized by <i>G. nephantidis</i>	Total adults of <i>G. nephantidis</i> emerged	No. of adults of <i>G. nephantidis</i> emerged/larva	No. of <i>O. arenosella</i> larvae parasitized by <i>H. hebetor</i>	Total adults of <i>H. hebetor</i> emerged	No. of adults of <i>H. hebetor</i> emerged/larva
10-01-15	7	44	6.29	12	68	5.67
31-01-15	9	54	6.00	10	67	6.70
01-02-15	12	71	5.92	8	33	4.13
15-02-15	17	113	6.65	7	53	7.57
07-03-15	16	104	6.50	7	45	6.43
22-03-15	21	130	6.19	13	62	4.77
05-04-15	36	275	7.64	21	122	5.81
24-04-15	41	246	6.00	27	134	4.96
09-05-15	48	312	6.50	36	149	4.14
17-05-15	52	347	6.67	46	213	4.63
06-06-15	15	90	6.00	20	85	4.25
21-06-15	10	78	7.80	12	72	6.00
05-07-15	7	41	5.86	2	11	5.50
25-07-15	6	35	5.83	1	6	6.00
15-08-15	5	30	6.00	0	0	0.00
29-08-15	6	25	4.17	0	0	0.00
12-09-15	5	44	8.80	0	0	0.00
22-09-15	4	31	7.75	2	10	5.00
06-10-15	4	25	6.25	6	29	4.83
24-10-15	12	77	6.42	8	43	5.38
14-11-15	17	108	6.35	7	45	6.43
29-11-15	14	88	6.29	8	41	5.13
05-12-15	15	103	6.87	7	38	5.43
20-12-15	18	143	7.94	3	16	5.33
-	-	Av. ± S.D.	6.53 ± 0.93	-	Av. ± S.D.	4.75 ± 2.01

Moreover, the total number of *O. arenosella* larvae parasitized by both parasitoids was maximum during the 2nd fortnight of May (98 larvae) followed by the 1st fortnight of May (84 larvae) and it was found to be minimum (5 larvae) during 1st fortnight of the August and 1st fortnight of the September.

The present findings are more or less in accordance with Farrugia (1981) who reported the occurrence three parasitoids species viz., *G. jacinta* sp. n., *G. collessis* sp. n. and *G. mandibulatus* sp. n. Further, Kapadia (1987) who note that the maximum parasitism by *P. nephantidis* was 5.98 per cent in November month. The average parasitism during throughout four years was maximum in February (3.66%) and the activity of the parasitoid was low in May (1.04%). Gubbaiah and Revanna (1989) reported that the larval parasitoids [*B. brevicornis* and *P. nephantidis* (*G. nephantidis*)] and pupal parasitoids (*Brachymeria* spp.) occurred naturally on *O. arenosella*; Desai *et al.* (2003) noted the highest percentage of parasitism of *G. nephantidis* was observed during all year. The pest intensity was decreased from June onwards and the intensity was very low in July-September. Earlier, Pillai and Nair (1995) reported that *B. hebetor*, *B. brevicornis* and *G. nephantidis* parasitized the larvae of *O. arenosella*. Pushpalatha and Veeresh (1995) recorded the three species of natural enemies on *O. arenosella* viz. *G. nephantidis* and *Apanteles taragamae* Vierick, and the carabid predator, *Parena nigrolineata* (Chaudoir); Jongok and Seunghwan (2006) reported five species of *Goniozus* on *O. arenosella* in Korea viz., *G. koreanus*, sp. nov., *G. mesolevis* Lim, sp. nov., *G. akitsushimanus*, *G. yoshikawai* and *G. maurus*. Shivanand and Deshapande (2011) revealed that the activity period of larval parasitoid, *Goniozus* sp. observed from second week of August to second week of November. The peak parasitization of *Goniozus* sp. was observed (17.50%) during the first week of October for sorghum ear head caterpillar, *H. armigera* under field conditions and this report is disagreed with present investigation.

The present findings are akin to Deen and Bhagat (2009) who stated that larva and pupae of *Pieris rapae* (Linnaeus), *Pontia daplidice* (Linnaeus) and yielded three parasititoids, viz. *Cotesia glomerata* (Linnaeus), *Hyposoter rebeninus* (Gravenhorst) and *Brachymeria femorata* (Panzer). *H. rebeninus* was witnessed as predominant of these parasitoids. It was found active in the field from June to October and the highest extent of parasitism caused to its host pests, *Pieris rapae* (Linnaeus) and *Pontia daplidice* (Linnaeus) was recorded as 28 and 22 per cent, respectively. Tanwar *et al.* (2011) indicated that natural parasitization of *A. bambawalei* on *Phenacoccus solenopsis* (Tinsley) and reached maximum extent as 90 per cent; Anand and Sujata (2013) found that *Apanteles* sp. was noticed in the first week of February with 2.00 per cent parasitism. While the maximum 21.17 and 11.39 per cent parasitism was recorded in the fourth week of February for the major parasitoids, *Euderus lividus* (Eulophidae), and *Ormyrus orientalis* (Ormyridae), respectively. Ansar, *et al.* (2014) found that *Conogethes punctiferalis* Guenee parasitized by two larval parasitoids viz, *A. taragamae* and *Glyptapanteles* sp. The incidence of larval parasitoids was maximum in the month of second fortnight of October. The per cent natural parasitization by larval parasitoids ranged from 3.36 to 43.31 per cent and pupal parasitoids ranged from 0.23 to 1.23 per cent; Veeramuthu *et al.* (2015) revealed that the July to December was found to be most favourable to the hymenopteran insects. Vanitha (2015) documented three eulophid parasitoids viz. *Chrysocharis* sp., *Closterocerus* sp. and *Aprostocetus* sp. on the larvae of cashew leaf miner, *A. syngamma*. Among the parasitoids, *Chrysocharis* sp. was dominant and recorded 99.0 per cent abundance with parasitism ranged from 37 to 58 per cent.



*SUMMARY
AND
CONCLUSION*



V. SUMMARY AND CONCLUSION

The studies on “Biology and parasitic potential of ecto-larval parasitoid, *Goniozus nephantidis* (Muesebeck) (Bethyridae: Hymenoptera) under South Gujarat conditions” were carried out in the P.G. Research Laboratory and Bio-control Laboratory, Department of Entomology, N.M. College of Agriculture, Navsari Agricultural University, Navsari during 2014-15 and 2015-16. The results derived from these investigations are summarized and concluded as under.

5.1 Biology of *G. nephantidis* on *C. cephalonica*

Studies on the biology of parasitoids provide information regarding various life stages and their behaviour which would be helpful in identifying the parasitoid stage and its potential in its life cycle for better pest management. Therefore, the present investigation on the biology of *G. nephantidis* on factitious host, *C. cephalonica* revealed that the maximum numbers of eggs of *G. nephantidis* were laid on the on dorso- lateral side of 5th to 6th abdominal segments of *C. cephalonica* larvae and there were not any eggs on the first segment of abdomen and thorax, while the last segment of abdomen. The each egg was loosely attached to the host's integument and deposited parallel to the longitudinal axis of the body. The freshly laid eggs were creamy white in colour and become translucent later. The deposited eggs were spindle shaped slightly curved, hyaline colourless and loosely attached to the surface of the host body. The length of eggs varied from 0.37 to 0.59 mm with an average of 0.48 ± 0.06 mm, whereas the breadth ranged from 0.18 to 0.29 mm with an average of 0.23 ± 0.03 mm. The incubation period was ranged from 1.0 to 3.0 days with an average of 2.10 ± 0.71 days. The egg hatching of *G. nephantidis* varied from 75.71 to 95.24 with an average of 87.03 ± 5.86 per cent.

The first instar larva was apodous, white, devoid of any sign of external segmentation and distinguished from the egg only by

waves of internal content of gut contraction and the movement of haemolymph within the parasite's body. The later instar larvae were whitish yellow and having clear larval segmentation. The full grown larvae with tapering ends and bulge middle portion of larval body. The larval length of *G. nephantidis* varied from 1.92 to 2.41 mm with an average of 2.17 ± 0.11 mm. The breadth of larva varied from 0.29 to 0.56 mm with average of 0.43 ± 0.08 mm. The larval period of *G.* varied from 3 to 5 days with an average of 4.03 ± 0.81 days.

The final instar larva ceased feeding and then search suitable place, where it remained stationary. This formed the beginning of cocoon formation stage. The cocoon of *G. nephantidis* was made loosely woven by silken threads and white in colour with oblong in shape and become tough attached with substrate. The length of *G. nephantidis* cocoon varied from 3.05 to 5.13 mm with an average of 3.98 ± 0.61 mm; while breadth ranged from 1.07 to 2.91 mm with an average of 1.98 ± 0.52 mm. The duration of pre-cocoon stage varied from 1.0 to 2.0 days with an average of 1.53 ± 0.51 days. The duration of cocoon period varied from 4.0 to 7.0 days with an average of 5.53 ± 1.00 days.

The newly emerged adults were black in colour with transparent membranous wings, head of the adults were also black in colour and blunted triangular in shape with sharp brown to black colour mandibles. The antennae were filliform with 13 segmented. The abdomen of females was bulged at anterior portion and posterior end sharp with pointed ovipositor. The male abdomen was differs from females due to short and blunted posterior tip. The length of the male was shorter as compared to females. The length of male varied from 1.06 to 1.65 mm with an average of 1.25 ± 0.13 mm and breadth varied from 0.33 to 0.81 mm with an average of 0.51 ± 0.13 mm, while the body length of female varied from 1.22 to 2.90 mm with an average of 1.83 ± 0.42 mm and breadth varied from 0.35 to 1.55 with an average of 0.94 ± 0.30 mm.

The pre-oviposition period varied from 3.0 to 6.0 days with an average of 4.70 ± 0.95 days. The oviposition period varied from 13.0 to 25.0 days with an average of 18.63 ± 3.27 days. The post oviposition period varied from 2.0 to 5.0 days with an average of 2.80 ± 0.76 days. The sex ratio of male as to female varied from 1: 2.60 to 1: 6.33 with an average of 1: 4.45. The per cent of adult emergence of *G. nephantidis* on *C. cephalonica* varied from 71.43 to 91.67 with an average of 83.06 ± 5.38 . The male longevity of *G. nephantidis* on *C. cephalonica* varied from 9.0 to 19.0 days with an average of 13.77 ± 3.05 days, while female longevity varied from 21.0 to 33.0 days with an average of 26.40 ± 3.39 days. The fecundity of *G. nephantidis* varied from 47.0 to 94.0 eggs per female with an average of 72.57 ± 13.41 eggs per female. The duration of total life cycle of male varied from 21.0 to 33.0 days with an average of 26.97 ± 3.45 days. Moreover, female life cycle ranged from 33.0 to 47.0 days with an average of 39.33 ± 3.24 days.

The morphological description of *G. nephantidis* presented in this chapter will help to identification of the larvae, cocoons and adults stages under the field conditions. Further, the results also focused that the parasitoid, *G. nephantidis* had few good attributes like high fecundity, maximum eggs hatchability, preponderance of females and longer female longevity which will be helpful in the management of *Opisina arenosella* Walker through inundative release under the field conditions.

5.2 Parasitic potential of *G. nephantidis* on *C. cephalonica*

The present investigation on parasitic potential of *G. nephantidis* on factitious host, *C. cephalonica* revealed that parasitoid paralyzed the larva of *C. cephalonica* within 2 to 3 hours after release. Adults of *G. nephantidis* started biting and preparing the larvae of *C. cephalonica* for oviposition. The female examines the host for about 20 to 25 seconds. Adults move its antennae and searches around the larval body for suitable eggs laying position.

After the egg laying female showed parental care behaviour. The most preferred host body segments for egg laying of parasitoid was 5th to 6th abdominal segments. The number of larvae parasitized by adult parasitoid of *G. nephantidis* under laboratory condition varied from 4.0 to 8.0 with an average of 6.07 ± 1.55 . The clutch size of *G. nephantidis* varied from 6.0 to 14.0 eggs per larva with an average of 8.97 ± 2.09 eggs per larva during present investigation.

The parasitic potential of *G. nephantidis* presented in this chapter emphasized that the parasitoid had few remarkable attributes like aggressive nature, good parasitic potential with highest clutch size and parental care especially with respect to female parasitoids will help in the management of *O. arenosella* through inundative release under field conditions.

5.3 Relative toxicity of various insecticides against *G. nephantidis*

The present investigation on relative toxicity of different insecticides against adults of *G. nephantidis* was carried out under laboratory condition. The data in terms of percentage mortality recorded at 12, 24, 48 and 72 hours after insecticidal application and results derived from these investigations are summarized as under.

The pooled analysis data revealed that all the insecticidal treatments treated for their contact toxicity to the adults of *G. nephantidis* showed significant mortality except control treatment (0.00%). Moreover, the treatment of spinosad 0.002 per cent (17.50%) was at par with flubendiamide 0.0096 per cent (25.83%) and indoxacarb 0.01 per cent (30.00%) and it was followed by profenofos 0.075 per cent (38.33%), emamectin benzoate 0.0025 per cent (43.33%), quinalphos 0.05 per cent (46.67%), chlorpyrifos 0.05 per cent (55.00%), triazophos 0.05 per cent (61.67%) and dichlorvos 0.05 per cent (70.83%).

From the above all results, it can be seen that there was no insecticide under investigation found totally safe except control

(water spray) to the adults of *G. nephantidis*. However, spinosad 45 per cent SC was comparatively harmless to the adults. Moreover, indoxacarb 15.8 per cent EC, emamectin benzoate 5 per cent SG, quinalphos 25 per cent EC, flubendiamide 39.35 per cent SC and profenofos 50 per cent EC were slightly harmful. Pertaining to the triazophos 40 per cent EC, dichlorvos 76 per cent EC and chlorpyrifos 20 per cent EC were moderately harmful, while none of insecticide was categorized as harmful to the adults of *G. nephantidis*. It is inferred that the none of the insecticides can be considered completely safe for *G. nephantidis*. Nevertheless, release of parasitoids would be considered appropriate after 72 hours of application of insecticides on coconut plantation when activity of persistent. The spinosad 45% SC being harmless (<25% mortality) and indoxacarb 15.8 per cent EC, emamectin benzoate 5 per cent SG, quinalphos 25 per cent EC, flubendiamide 39.35 per cent SC, profenofos 50 per cent EC were slightly harmful (25-50% mortality) hence could be recommended for integration with IPM programme. The parasitoid should be released at least 72 hours after the application of insecticides. However, since triazophos 40% EC, dichlorvos 76 per cent EC, chlorpyrifos 20 per cent EC existed moderately harmful (51-75% mortality). The use of these insecticides in coconut plantations should be avoided up to 72 hours after release. However, in view of the possible detrimental effects of these pesticides on adult parasitoids, the use of these products should be considered with utmost care for IPM of coconut black headed catepillar

5.4 Natural occurrence of larval parasitoid on black headed caterpillar, *O. arenosella* under Navsari condition.

During the present investigation on natural occurrence of larval parasitoids of black headed caterpillar under Navsari conditions and it was found that the two larval parasitoids viz., *G. nephantidis*

and *H. hebetor* were noticed on *O. arenosella*. Among them, *G. nephantidis* was the dominant species throughout the year.

The maximum parasitism of *O. arenosella* by *G. nephantidis* and *H. hebetor* was noticed during 2nd fortnight of May (17.69 and 15.65%) and it was followed by the 1st fortnight of May (17.58 and 13.19 %) for the both parasitoids, respectively. While, minimum per cent of parasitism by *G. nephantidis* was noted during the 1st fortnight of the October (2.23%) and later on parasitism was increased up to 2nd fortnight of December (14.88%). Moreover, the per cent parasitism of *H. hebetor* was nil during the 1st fortnight of the August to 1st fortnight of the September. The highest number of *O. arenosella* larvae were parasitized by *G. nephantidis* and *H. hebetor* during the 2nd fortnight of May (52 and 46 larvae) and followed by the 1st fortnight of May (48 and 36 larvae) for the both parasitoids, respectively.

The total number of adults of *G. nephantidis* and *H. hebetor* emerged from host larvae was the maximum during the 2nd fortnight of May (347 and 213 adults) and followed by the 1st fortnight of May (312 and 149 adults) for the both parasitoids, respectively. Moreover, the number of adults of *G. nephantidis* emerged from single larva was highest during the 2nd fortnight of the September (8.80 adults/larva) followed by 2nd fortnight of the December (7.94 adults/larva) it was lowest during the 2nd fortnight of the August (4.17 adults/larvae). While in case of *H. hebetor*, the maximum adults emerged from single larva was noticed during the 2nd fortnight of the February (7.57 adults/larva) followed by 1st fortnight of the February (6.70 adults/larva) and it was nil during 1st fortnight of the August to 1st fortnight of the September.

The ecto-larval parasitoids viz., *G. nephantidis* and *H. hebetor* found to be very effective in the natural regulation of the coconut black headed caterpillar, *O. arenosella*. Therefore, the above two parasitoids could be exploited in future for the field management

of *O. arenosella* in coconut growing belt of Gujarat as well as other parts of the country. To overcome the indiscriminate usage of harmful pesticides in coconut ecosystem, the effective conservation and augmentation of such naturally occurring potential larval parasitoids would be the future sustainable bio-control strategy for the management of *O. arenosella*.



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